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Consideration is given to the possibility of providing a computer and a cathode ray printer with an unlimited repertory of characters. Digitalizations are presented for mathematic, cartographic, and calligraphic characters. The repertory is available to any computer through FORTRAN IV programming. The latest cathode ray printers are almost adequate for the preparation of mathematical reports. Some progress has been made toward development of a mnemonic code for the recording of a mathematical text on tape.

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TECHNICAL REPORT

CALLIGRAPHY FOR COMPUTERS

by

A.V. HERSHÉY
Computation and Analysis Laboratory



U. S. NAVAL WEAPONS LABORATORY
DAHLGREN, VIRGINIA

U. S. Naval Weapons Laboratory.
Dahlgren, Virginia

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ABSTRACT

Consideration is given to the possibility of providing a computer and a cathode ray printer with an unlimited repertory of characters. Digitalizations are presented for mathematic, cartographic, and calligraphic characters. The repertory is available to any computer through FORTRAN IV programming. The latest cathode ray printers are almost adequate for the preparation of mathematical reports. Some progress has been made toward development of a mnemonic code for the recording of a mathematical text on tape.

FOREWORD

The work of this report represents an advance in the application of computers. Programming and computation were charged to the Foundational Research Program of the Naval Weapons Laboratory, Project No. R360FR103/2101/R0110101. Character displays were programmed for the NORC cathode ray printer by W. H. Langdon, and for the STRETCH cathode ray printer by Mrs. E. J. Hershey. The photo-microgram of Figure 1 was prepared by J. P. Rucker. Dot plots were prepared on an S-C 4010 printer at the Naval Weapons Laboratory and vector plots were prepared on an S-C 4020 printer at the Naval Ship Research and Development Center. The manuscript was completed by 1 Aug 1967. The Japanese Lexicon was checked by Educational Services of Washington, D. C.

APPROVED FOR RELEASE:

/s/ BERNARD SMITH
Technical Director

INTRODUCTION

Although computers are used primarily for arithmetic, there are other ways in which computers can be used for the saving of labor. The use of computers and cathode ray printers for typesetting^{1,2} is receiving much attention at the present time. Publishers are interested in the possibility of reducing the cost of printing and scientists are interested in the possibility of improving the versatility of printing.

The objective of the present investigation is to explore the feasibility of utilizing the computers and cathode ray printers at the Naval Weapons Laboratory for the preparation of mathematical reports. In this connection a large repertory of digitalized characters has been prepared. The repertory was intended to correspond in scope to the repertoires of the American Institute of Physics³ and the American Mathematical Society⁴. The virtuosity of the cathode ray printer has been explored further with a number of calligraphic digitalizations.

Although a number of printer systems² currently are under development, it is assumed in the present report that the Linotron equipment of the Mergenthaler Linotype Company and the Charactron equipment of the Stromberg-Carlson Corporation may serve as examples to illustrate representative qualities, speeds, and versatilities. The repertory in the present report is intended to fill a need for a system which does not sacrifice too much quality or speed, but is unlimited in versatility.

A digitalization of characters was undertaken originally at the Naval Weapons Laboratory⁵ for use on dot plotters. An improved version of the original digitalization is presented herewith as Appendix A. With the exception of a few of the characters, no

attempt was made to vary line thickness.

A digitalization of characters has been prepared recently at the Bell Telephone Laboratories⁶ for use on vector plotters. Line thickening was achieved through the use of multiple lines one raster unit apart. The style of character has been limited so far to Roman and Greek lower case and upper case. The remarkable success of the line thickening has been a stimulus to an extension of the same technique to exotic graphics.

The digitalizations at the Naval Weapons Laboratory and at the Bell Telephone Laboratories complement each other insofar as they do not overlap from the standpoint of style or height of character.

A digitalization of characters is currently under preparation at the Naval Weapons Laboratory for use on vector plotters. Details of the current digitalizations are presented herewith as Appendix B. The scope of the digitalizations is indicated by the following table.

CHARACTER DIGITALIZATIONS

I SIMPLEX

Roman, Greek, Script, Numeric, FORTRAN, Electronic,
Cartographic.

II DUPLEX

Roman, Greek, Italic, Futura, Script, Russian, Numeric,
Mathematic, Astronomic, Musical.

III TRIPLEX

English Gothic, Italian Gothic, German Gothic.

IV JAPANESE

Hiragana, Katakana, Kanji.

Some of the alphabets in the table have been given new names because they are not identical with existing alphabets. The word simplex has been selected to describe those alphabets which are composed of lines of uniform thickness and have no serifs or flourishes. The simplex style of character is known otherwise as gothic*, sans serif, grotesk, light face, or block letter. The word complex may be applied to those alphabets which are composed of lines of variable thickness and do have serifs or flourishes. The complex style of character includes those which are known otherwise as standard, modern, boldface, or black letter. The words uniplex, duplex, multiplex may be used to express the number of lines which are used in parallel to obtain a variation in line thickness.

Three sizes of characters are provided by the repertory in Appendix B. Characters 9 raster units in height are available for FORTRAN or cartographic applications. Characters 13 raster units in height are available for indexical lines of print. Characters 21 raster units in height are available for principal lines of print.

PRINTING SYSTEMS

Character Generation

In cathode ray printing systems, characters are displayed on the face of a cathode ray tube and are photographed by a camera. Two distinct methods are used for the creation of a character on the face of the cathode ray tube. In one method, a character is created by a beam of electrons which is shaped by its passage through an aperture in a matrix. In the other method, a character is created from the strokes of an electron beam with a constant sweep rate.

*Only in America is the term gothic applied to this style of character.

The space occupied by a character and the time required to create the character are constant for shaped characters but depend upon the size and complexity for stroked characters. In order to compare the methods of creating characters, weighted averages of space and time are required. Weighted averages may be derived through summation of the product of space or time for each character by the frequency of occurrence of the character as utilized in cryptology⁷.

Shaped characters and stroked characters both may be created with the Charactron printers.

Charactron Printers

The cathode ray printers at the Naval Weapons Laboratory consist of an S-C 4010 printer¹¹ on line to the Naval Ordnance Research Computer, and an S-C 4010 printer¹² off line to the STRETCH computer. These are dot plotters and have no vector plotting capability beyond axis generation. The shaped characters occupy 8 raster units of width and require 58 microseconds of time. The matrix contains only 64 characters. Stroked characters can be plotted with the aid of vector simulation subroutines, or the characters can be created out of dots as in Appendix A. A representative weighted average of width for dot plots is 17 raster units and a representative number of dots per character is 22. The plotting of each dot requires 85 microseconds of time.

In the S-C 4020 printer¹³ a vector plotting capability is added to the dot plotting capability of the S-C 4010 printer. Stroked characters can be created out of vectors as in Appendix B. A representative weighted average of width for vector plots is 18 raster units and a representative number of vectors per character is 19. The time to plot each vector depends upon the time to decode the plot instruction and the time to sweep the vector. A representative decoding time is 85 microseconds and a representative sweep rate is $\frac{1}{2}$ raster unit per microsecond. The size of the raster is 1024 X 1024.

In the S-C 4060 printer¹⁴, ¹⁵ the speed and repertory have been increased. Four sizes of shaped characters are provided, and the shaped characters require 11 microseconds of time for creation. The matrix contains 115 characters and includes both lower case and upper case. Four sizes of plotting dot are provided. A representative decoding time is 15 microseconds and a representative sweep rate is 2 raster units per microsecond. The size of the raster is 3072 × 4096 and the size of the raster unit is the same on both axes. The longer dimension of the raster is in the longitudinal direction on the camera film. The fineness of the raster cannot be utilized fully for stroked characters because of limitations on the fineness of resolution. The smallest plotting dot is three raster units in diameter according to measurements on a specimen of hard copy.

Linotron Printers

In the Linotron printer the characters are stored as photographic images on four glass plates. Any selected character is scanned photo-electrically in a succession of horizontal sweeps across the character block. The photoelectric signal is displayed on a cathode ray tube. The selection, enlargement, and deflection of each character all are performed electrically. The time to create a character depends upon the size of character. For 6, 8, 10 point sizes of character the printing speed is quoted¹⁶ at 1000, 800, 620 characters per second, respectively. The characters are of graphic arts quality on an $8 \times 10\frac{1}{2}$ inch page size. The repertory includes 1020 characters of which a few are mathematical. However, the present scope of the Linotron project does not extend to chemical and mathematical composition.*

Relative Speeds

Insofar as the data in the above considerations are representative

*The existing repertory does not include the integral sign or the partial differential symbol.

of actual performance, the data in the following table are representative of printing speeds.

Printing System (stroke vs shape)	Printing Speed (characters/second)
Dot plot on S-C 4010	530
Vector plot on S-C 4020	550
Vector plot on S-C 4060	2200
Print on Linotron	620
Print on S-C 4010	17400
Print on S-C 4020	17400
Print on S-C 4060	90000

The above estimates do not include the time on a general purpose computer which would be required for the preparation of input to the cathode ray printers.

RESOLUTION

Model

In order to gain some insight into possible factors in the resolution of a cathode ray printer, an analysis will be made on a specific model in which the raster on the cathode ray screen covers an area 10 cm \times 10 cm square and contains 1024 \times 1024 raster units. It will be assumed that hard copy from the cathode ray printer covers an area 6" \times 6" and is viewed by a reader's eye at the conventional distance of 10".

Acuity

A limiting factor is the acuity of the eye. Any resolution in excess of the amount which can be perceived would be wasted. The acuity of the eye varies among individuals, and the acuity varies with the type of perception. Insofar as the perception of separation between lines is a gauge of acuity, the angle of resolution¹⁰ is 30" of arc or a quarter of a raster unit.

Diffraction

An interesting factor is the diffraction of electrons or light in the printer system. The diffraction pattern of a circular aperture consists of alternating bright and dark rings around the geometric center. The angle θ which is subtended by the diameter of the first dark ring is given by the equation

$$\theta = 2.44 \frac{\lambda}{d} \quad (1)$$

where λ is the wave length and d is the diameter of the circular aperture. The wave length for electrons is given by the equation*

$$\lambda = \sqrt{\frac{150}{V}} \times 10^{-8} \text{ cm} \quad (2)$$

where V is the voltage through which the electrons have been accelerated before diffraction.

The paths of the electrons which enter an aperture of the matrix have some dispersion of direction because of the finite aperture of

*This equation is given in the Encyclopaedia Britannica⁸ but not in the Handbook of the American Institute of Physics⁹!

the electron gun, and the dispersion is increased further by diffraction at the aperture. Regardless of the dispersion, all electrons which emanate from a given point in the aperture would be brought to a focus at a common point on the screen if the focusing were perfect.

The effect of diffraction applies to the aperture of the focusing system. It is assumed that the electrons are at 3300 volts when they are diffracted at an aperture of 1 cm diameter and at a distance of 50 cm from the cathode ray screen. The diameter of the first dark ring is computed to be less than 3×10^{-5} raster units and the effect of electron diffraction is negligible.

It is assumed that the cathode ray screen is coated with RCA phosphor No. 11 which has a peak intensity of emission at a wave length of 4600 Å. It is assumed that the camera is operated at a lens aperture of f/5.6. The diameter of the dark ring of optical diffraction is calculated then to be 0.064 raster units.

Grain Size

It is assumed that the diameter of the grains of the phosphor is 5 microns. The grain diameter then corresponds to one twentieth of a raster unit. That the grain size is small also on the film in the camera is indicated by Figure 1. This photomicrograph is a 650 X magnification of a dot which has been recorded on film in the NORC cathode ray printer.

Aberration

One factor which affects resolution is the effect of aberration on the focusing of the electron beam. A diffuse character of the plotting dot can be discerned in Figure 1. The diffuseness may be greater still in a cathode ray printer which is not maintained in perfect adjustment. The diffuseness has the beneficial effect in a dot plotter of making it

possible for a series of closely spaced dots to merge into a continuous line. The diffuseness has the deleterious effect in a vector plotter of bridging small gaps or of filling small openings in the characters. Due allowance must be made in the design of the characters to avoid these unacceptable effects. A gap in a line may be smaller than the opening within a circle without undue bridging or filling.

Dot Size

From densitometer readings it has been determined that the effective diameter of the plotting dot is 2.9 raster units for the S-C 4010 printer. A diameter of 2.3 raster units has been reported⁶ for the S-C 4020 printer. That the diameter could be as small as one raster unit for the same printer is implied by measurements on the hard copy sample from the S-C 4060 printer. It is evident that the cathode ray printers do not achieve the ultimate in resolving power.

The diameter of the plotting dot in a vector plotter should be a minimum in order to give a maximum control of line thickness. The diameter must be no less than one raster unit in order that solid areas may be swept out. The fineness of strokes which can be printed on current cathode ray printers is limited by dot size and not by raster size.

Raster Size

A line of text in a mathematical document should be long enough so that the mathematical equations which are inserted in the text only rarely need to be broken with part on one line and part on another line. With the model herein adopted for analysis, the length of a line of text is 6". If this were typewritten in elite style at 12 characters per inch there would be 72 characters per line of text.

If the line of text were printed with stroked characters at 18 raster units per character, then 1296 raster units would be required per line of text. This is not too many characters per line. Although the number of characters per line is less than 72 for the texts of the American Institute of Physics³ or the American Mathematical Society⁴, it may be more than 72 for the texts of the Cambridge University Press¹⁷.

Requirements

It seems apparent that the S-C 4010 and the S-C 4020 cathode ray printers do not have small enough plotting dots and large enough rasters to meet the requirements for the printing of mathematical texts. The S-C 4060 cathode ray printer could meet the requirements if the plotting dot were truly 2 raster units in diameter and the starting and stopping of vectors were controlled to within a raster unit.

CHARACTER DESIGN

Design Criteria

There would be no problem in copying any existing character if the cathode ray printer did not have a finite plotting dot and a finite raster size. The problem of design arises from the need to make a compromise between the three factors of smallness, smoothness, and legibility. It is desirable to make the characters as small as possible so that as many characters can be printed on a line of print as possible. It is desirable to make the edges of curved lines smooth so that characters may have a professional appearance. It is essential that there be no loss of legibility because of bridging or filling of small gaps. The finest detail in any character of an alphabet sets a limit on the smallness of character for the whole alphabet.

The problem of digitalization is to locate successive points in a relatively coarse grid such that vectors can be drawn between the points with optimum results. The absolute position of the successive vectors is not so important as the relative orientation of the successive vectors. With an application of ingenuity it often is possible to achieve a pleasing effect with the polygonalization of curved lines. The limitation on digitalization which is imposed by the finiteness of the grid constitutes an artistic challenge. It is not obvious a priori that all of the characters of interest can be digitalized.

Character Size

A satisfactory polygonalization of a small circle is not possible for a circle of any arbitrary size. The number of sides of the polygon is related to the size of the polygon. The smallest sizes are an octagon of 4 or 6 raster units diameter and a dodecagon of 8 raster units diameter. The next two sizes are hexadecagons with 10 or 14 raster units diameter. The choice of diameter is related to the fact that the polygon appears round only if it has the same radius at 45° inclinations as it has at 0° or 90° inclinations. The products of $\sqrt{2}$ and the smallest integers are approximately integral only if the integers are 5 or 7.

From a mathematical standpoint, an ellipse would be polygonalized by a polygon which is tangent to the ellipse at the point of contact between ellipse and polygon. The ellipse may be found by simultaneous solution of the equation

$$\frac{x^2}{a^2} + \frac{(y - b)^2}{b^2} = 1 \quad (3)$$

for the ellipse, and the equation

$$\frac{dy}{dx} = - \frac{b^2}{a^2} \frac{x}{(y - b)} \quad (4)$$

for the slope of its tangent. In these equations a and b are principal radii of the ellipse. Solution leads to the equation

$$\frac{y}{x} = \frac{-1 + \sqrt{1 + \frac{a^2}{b^2} \left(\frac{dy}{dx} \right)^2}}{\frac{a^2}{b^2} \frac{dy}{dx}} \quad (5)$$

Along a side of the polygon, x and y are related linearly, and the slope dy/dx is constant. The point of tangency between ellipse and polygon may be found by the solution of two simultaneous linear equations in x and y . A number of solutions have been obtained, but only the solutions in the following table are within reasonable bounds.

Side of Polygon	Height of Ellipse
$y = \frac{1}{4}(x - 2)$	$2a = 22.0$ for $\frac{b}{a} = \frac{2}{3}$
$y = \frac{1}{3}(x - \frac{3}{2})$	$2a = 18.5$ for $a = b$
$y = \frac{1}{2}(x - 1)$	$2b = 18.5$ for $\frac{a}{b} = \frac{2}{3}$

The height for polygonalization is not well defined but seems to range from 18 to 22 raster units.

Professional printers measure the size of type in points such that one inch equals 72 points. The point size of type is the normal distance from the base line of one line of type to the base line of the next line of type. The design of character within a character block depends upon the amount of white space which is to be provided between lines of type. Printers often increase the white space to more than normal with additional leading between lines of type. The normal distance from one line to the next is one em, which is subdivided further into printers units such that one em equals 18 units.

A natural correlation between mechanical printing and cathode ray plotting would be achieved if a printer's unit were equated to an integer number of raster units. Insofar as a representative height of character is 12 printer's units, a representative height of character would be 12 or 24 raster units.

In the printing of mathematical texts the principal line of type is printed in 10-point type while the indexical lines of type are printed in 6-point type. The sizes of character in raster units should be compatible with two kinds of line of type.

In the Roman alphabet some lower case letters are two-thirds as high as the upper case letters. The height of the upper case letters should be a multiple of three. Many lower case letters are round, while several upper case letters are oval. The Arabic numerals have round parts. The various round characters should be coordinated with small circles. In the Italic alphabet there are slant lines of various lengths. The projection of each slant line on the horizontal axis is a small integer. For a given slope of line the height of line can have only a few values. Typical slopes for actual Italics are 1 to 3 or 4.

The above considerations have led to a choice of 14 raster units as the basic width and 21 raster units as the basic height of the upper case letters of principal lines of type, and a choice of 10 raster units as the basic width and 13 raster units as the basic height of the upper case letters of indexical lines of type.

Character Space

Calligraphers²⁵ advocate the use of the style of Roman lettering on the Trajan column. This style may be appropriate for architecture but the letters vary greatly in width. Inasmuch as the lettering in the present alphabets is intended to be used interchangeably in words of a text or as symbols in a graph, the letters have been designed to appear

uniform in width.

Calligraphers²¹, ²² agree that the white spaces within letters and between letters should have a uniform distribution along a line of print. This is not really possible in the presence of the letter pairs AA or VV, but these letter pairs are rare. The spacing which should be allotted to each letter varies with the environment in which the letter is situated, and it even has been proposed that the width of the letter itself should vary with its environment. In the present alphabets each character block is allotted its own width, but the width can be changed to any other value as may be desired under program control in the computer.

Character Style

The digitalizations of simplex alphabets are adaptations of the alphabets on Le Roy lettering sets. The digitalizations of complex Roman, Greek, Italic, Russian alphabets are adaptations of the alphabets to be observed in newspapers, text books, and dictionaries¹⁸, ¹⁹.

Script and Gothic Alphabets

Originally there was only one style of Roman lettering, but the need for a rapid cursive handwriting resulted in a rounding of angularity with the formation of the uncial style of lettering. Now there are two sets of characters for each style of lettering. The majuscules are used for initials and are known otherwise as capitals or upper case letters. The minuscules are used for text, and are known otherwise as small letters or lower case letters. Further evolution of the minuscules resulted in Script for writing and Gothic for printing.

Characters from these alphabets are borrowed occasionally by mathematicians to represent special quantities.

Digitalization of the script alphabet has been adapted from a Headliner Typemaster of the Varityper Corporation. The first Gothic alphabet has been adapted from a Le Roy lettering set for Old English and is called English Gothic. The second Gothic alphabet represents a large family of alphabets for which there does not seem to be a consistent nomenclature. Some writers refer to it as Gothic uncial while others call it Lombardic Gothic. It seems to have been developed in Lombardy while the best examples²³, ²⁴ seem to come from Spain. The present version is an adaptation of a font of the American Type Founders Company²⁰. It is being named Italian Gothic because of its Lombardic origin. The third Gothic alphabet is an adaptation of Fraktur²⁵ and is named German Gothic.

Musical Symbols

The digitalization of musical symbols depends upon the spacing between the lines of the staff. A whole note can be centered over a line only if its height is an even number of raster units. The note can be centered between lines if the spacing between lines is even. A whole note can straddle a line without undue filling and numerals 13 raster units high can be used for measure signs if the spacing between lines is selected to be 10 raster units.

Japanese Characters

The ultimate challenge to calligraphy for computers is the imitation of brush strokes in Chinese and Japanese characters. An investigation has been made to determine the feasibility of digitalization of the Japanese characters. The results are given in Appendix C. The results even have been used for the preparation of an abstract of a Naval Weapons Laboratory report in Japanese as well as in French and German.

Originally the Japanese had no way to write the Japanese language³¹. Chinese characters were introduced into Japan along with Confucianism and Buddhism. The structure of a majority of Chinese characters consists of two parts. One part defines the meaning while the other part defines the pronunciation. The two parts often are so selected as to express a logical or poetic meaning for the character.

The Chinese characters are used as stems of many words. Two or more Chinese characters often are grouped together to form compound words. The Chinese characters are called *kanji* by the Japanese. A character dictionary lists 5500 Chinese characters of common occurrence in the modern literature. There are many more in the classical literature. Many of the *kanji* have been simplified, and in November 1946 the Japanese Ministry of Education selected 1850 *kanji* to be used in newspapers and official documents. These are called *Tōyō Kanji* or current characters. They constitute much too restricted a list for technical writing, and even the abstract which is referred to above is not confined to the list.

Parts of certain Chinese characters have been abstracted by the Japanese to form two phonetic syllabaries. The phonetic characters are called *kana* by the Japanese. The *hiragana* syllabary is used as the inflection of words and the *katakana* syllabary is used for foreign words or telegrams. There are 48 basic characters in each phonetic syllabary. Some of these may be modified by diacritical marks or *nigori* to make 25 additional characters. The number of phonemes is 73 for each syllabary.

Each Chinese character has one or more pronunciations of Chinese origin which are called *on*. The Chinese characters for common things also have a Japanese pronunciation which is called *kun*. When Chinese characters are used individually or with a Japanese inflection they are given the *kun* pronunciation. When they are joined together in a compound word they are given the *on* pronunciation. There are only 326 *on* pronunciations to be distributed among 5500 characters. Each

on pronunciation applies therefore to many characters. Ambiguity is avoided insofar as each *on* occurs only within the context for which it has a unique interpretation. The pronunciations can be transliterated into the Roman alphabet in accordance with the Hepburn system. The Romanization is called *rōmaji* by the Japanese. Certain vowel sounds are suppressed while others are lengthened in certain pairs of *kana* which are transliterated into distinct phonemes. There are 114 phonemes in the *rōmaji*.

The structure of each Chinese character consists of one or more parts. One part of every character is called a radical. There are 214 radicals. Many of the radicals are themselves complete characters, while other radicals no longer are used except as parts of characters. To find a character in a character dictionary the first step is to recognize the radical in the character. The radicals are listed serially in the order of increasing number of strokes in the index of the dictionary. All characters with the same radical are listed together in the order of increasing number of strokes in the body of the dictionary. The problem of finding a character thus is reduced to the scanning of a relatively small number of pages in the dictionary.

Character Selection

In view of the large number of characters in a character dictionary, severe limitations had to be imposed on the selection of characters for digitalization. The scope of selection of characters was limited to three sets of characters. The first set includes those radicals which are members also of the *Tōyō Kanji* list. The second set includes those characters which are taught to the Japanese children in the first grade. The third set is a selection of characters of scientific interest. A character which was found to be a component of two or more compound characters was certain to be included. If one character of a pair of antonyms was accepted, the other character was included also, or if

one character of a set of characters was accepted, other characters in the set were included. It was impossible to cover more than a small part of any one subject, and the list of characters is illustrative rather than comprehensive, but it should be well balanced as far as it goes.

The choice of characters was checked by a closed circuit through the dictionaries²⁶⁻³⁵. Starting with an English to *kanji* dictionary, the *kanji* for a selected English word was found, then continuing with the character dictionary, the *rōmaji* of the given *kanji* was found, and ending with a *rōmaji* to English dictionary, the *kanji* and English for the given *rōmaji* were found. Thus the final English word could be checked against the initial English word.

In the character dictionaries each character is followed first by the *on* pronunciation, second by the *kun* pronunciation, with English translations wherever possible, and finally by a table of compounds wherein the character appears. Although many of the individual characters no longer are used alone and appear only as components of compounds, they still are given archaic English translations, which would unbalance an abridged list of morphemes. Furthermore, certain grammatical morphemes do not occur in the character dictionaries because they have only phonetic renderings. It appears that the best way to illustrate the use of digitalized characters is by a dictionary listing analogous to Sanseido's³³. Each entry in the listing is punched on a separate punch card in the order *rōmaji-kanji-kana-English*. The deck of cards may be sorted, abridged, or augmented easily. Its present status is illustrated in Appendix D.

Each character in Nelson's dictionary³² is assigned its own number, whereas the characters in other dictionaries are located by page number. Inasmuch as the numbering in Nelson's dictionary provides a natural and definite identification, it has been adopted for the numbering of digitalized characters. It is easy to recover the character

by its number from the dictionary.

The style of character which seems most promising for digitalization is represented by the simplified square characters in Nelson's dictionary ³². These contain hairline horizontal strokes, tapered inclined strokes, and heavy line vertical strokes. Before the characters can be digitalized a decision must be made as to the conversion factor to be used for length from inches to raster units.

Character Conversion

The simplest character of all is No. 0001 (*ichi* = one). It consists of a horizontal line with a triangular spot at the right end. The thickness of the line is 0.010 in. and the length of the line is 0.270 in. The triangle has a base line of 0.060 in. and an altitude of 0.040 in. The vertex of the triangle is 0.010 in. to the left of the center of its base line.

Character No. 0768 (*jū* = ten) differs from character No. 0001 by the addition of a vertical stroke. The horizontal stroke is reduced to a thickness of 0.005 in. and a length of 0.260 in. The triangle has a base line of 0.055 in. and an altitude of 0.034 in. The vertical stroke has a thickness of 0.032 in. and a height of 0.258 in.

Character No. 2170 (*ki* = tree) differs from character No. 0768 by the addition of a pair of diagonal and curved strokes which extend downward to the left and to the right from the center. The horizontal stroke has a length of 0.254 in. and the vertical stroke has a height of 0.263 in. This character occurs as the radical of an especially large number of other characters. When it is used as a radical it is compressed horizontally. In character No. 2379 (*ki* = opportunity) the horizontal stroke has a length of only 0.093 in. The triangular spot has a base line of 0.030 in. and an altitude of 0.020 in.

Thus the thickness and size of components vary in ranges which depend upon the range of fineness of detail. In order to reproduce the above ranges of line thickness and triangle size the conversion may be determined to be 0.011 inches per raster unit. This provides two widths of vertical stroke and three sizes of triangle provided the plotting dot is not more than one raster unit in diameter, and due allowance is made for the thickness of line.

A critical determination of the conversion of length is provided by those characters where there is a set of equally spaced parallel strokes. The space between strokes must conform to an integral number of raster units. Any change of space between strokes then is magnified to a large change in the space allowance for the set. Measurements of spacing have been made upon sixty characters. From the measured distance which spans each set of equally spaced strokes it is possible to compute a distance per raster unit for every possible number of raster units per space. When these distances are plotted together for comparison it becomes apparent that there is a tendency for certain distances per raster unit to persist from character to character. There is some persistence around 0.011 inches per raster unit while there is a stronger persistence around 0.0055 inches per raster unit. The second value would allow the horizontal strokes to have just the right thickness for a full representation of detail but the characters would be twice as large.

Critical examples of characters with many equally spaced strokes are given in the table on the next page.

Character Number	Inches per Raster Unit	Inches per Raster Unit	Translation
0272	0.0115	0.0057	<i>koto</i> = fact
2141	0.0098	0.0059	<i>ryō</i> = quantity
2160	0.0108	0.0054	<i>kumoru</i> = cloud up
3113	0.0117	0.0053	<i>sara</i> = dish
3127	0.0103	0.0055	<i>me</i> = eye
4608	0.0112	0.0056	<i>kuruma</i> = vehicle
4883	0.0108	0.0054	<i>hagane</i> = steel

This table illustrates the degree of correlation between values for the conversion factor.

Although all characters are centered within the same square block, the overall size of many characters is not well defined because pointed strokes radiate outward in all directions from the interior. The size is really well defined only for those characters which are enclosed in a square radical. Examples with square enclosures are illustrated in the following table.

Character Number	Width	Height	Stroke Count	Translation
0868	0.165	0.155	3	<i>kuchi</i> = mouth
2994	0.178	0.188	5	<i>ta</i> = rice field
1028	0.190	0.202	6	<i>mawaru</i> = go around
1037	0.202	0.220	8	<i>kuni</i> = country
1045	0.208	0.233	12	<i>ken</i> = circle

The dimensions in the table are center to center between horizontal strokes or between vertical strokes in the external enclosure. The dimensions increase with complexity to a maximum of 21 raster units

when the conversion factor is assumed to be 0.011. This is compatible with the standard size of Roman alphabet.

The digitalizations in the present investigation are limited to characters with a nominal height of 21 raster units. With some omission of detail in tight spaces and some overflow in complicated cases this size is believed to be adequate for all characters in Nelson's dictionary except No. 5444. Inasmuch as this character represents dragons in motion, it is of doubtful utility. The remaining characters either have been simplified or can be digitalized without too much distortion provided the minimum spacing between lines can be as small as two raster units. Even character No. 5444 can be digitalized when the nominal height of character is 42 raster units.

DOT DATA

Smooth straight lines can be generated with a dot plotter only in limited directions where the discrete increments ΔX , ΔY from one dot to the next have simple integral values. Primary directions are generated when the lines are defined by the increments

$$(\Delta X, \Delta Y) = (2, 0)$$

$$(\Delta X, \Delta Y) = (2, 1)$$

$$(\Delta X, \Delta Y) = (1, 1)$$

or by any permutation of magnitude or reversal of sign among these increments. Secondary directions are generated when the lines are defined by alternation between the following pairs of increments

$$(\Delta X, \Delta Y) = (2, 0), (2, 1)$$

$$(\Delta X, \Delta Y) = (1, 0), (2, 1)$$

$$(\Delta X, \Delta Y) = (1, 1), (2, 1)$$

or by permutations or reversals among these. Jogs in the lines become perceptible when more elaborate patterns are used. The linear characters A, K, M, N, V, W, X, Y, Z contain a variety of inclined lines and limitations on the possible inclinations determine the shapes of the characters. The Roman style of character is available to a dot plotter, but the inclinations for an Italic style of character would be too exaggerated.

Dot plotting on NORC is accomplished by either of two character plotting routines. Block No. 0130 gives a mathematical repertory while Block No. 0160 gives a cartographic repertory. These NORC subroutines have been converted recently to FORTRAN IV by the Control Data Corporation.

The digital data for each character are packed in the data array of each subroutine. The data consist of decimal digit pairs. The first digit pair gives the half width of the character. The second digit pair gives the X -displacement and the third digit pair gives the Y -displacement to the first dot. The subsequent digit pairs give displacements to successive dots. In each of these digit pairs the first digit is the X -displacement and the second digit is the Y -displacement. Negative displacements are expressed by 9's complements. Whenever the first digit is 5, the previous displacement is repeated a number of times equal to the second digit. If the digit pair is 00, the next four digits are interpreted in the same way as the second and third digit pairs, except that displacements are relative to the last plotted dot. The digit pair 50 signifies the end of character.

The decimal format for NORC data is not suitable for STRETCH programming. Inasmuch as the NORC word is 16 decimal digits long and the STRETCH word is 64 binary bits long, there can be a one to one correspondence between the BCD datum word for NORC and the binary datum word for STRETCH. One decimal digit with 9's complements in NORC is mapped into three integer bits and one sign bit in STRETCH. An array of coordinates for dot plotting is recovered from memory by interrogation of a pair of STRAP subroutines.

Replacement of FORTRAN programming by STRAP programming in the character plotting routines has achieved a 7-fold reduction in machine time.

VECTOR DATA

Smooth straight lines are no problem for a vector plotter, but curved lines are approximated by polygons. Small polygons are constructed from short vectors whose components ΔX , ΔY have the following integral values

$$\begin{array}{lll} (\Delta X, \Delta Y) = (1, 0) & (\Delta X, \Delta Y) = (1, 1) & \\ (\Delta X, \Delta Y) = (2, 0) & (\Delta X, \Delta Y) = (2, 1) & (\Delta X, \Delta Y) = (2, 2) \\ (\Delta X, \Delta Y) = (3, 0) & (\Delta X, \Delta Y) = (3, 1) & (\Delta X, \Delta Y) = (3, 2) \\ (\Delta X, \Delta Y) = (4, 0) & (\Delta X, \Delta Y) = (4, 1) & \\ (\Delta X, \Delta Y) = (5, 0) & & \end{array}$$

or have any permutation of magnitude or reversal of sign among these values.

In the composition of a character, the ordering and the direction of vectors are immaterial for any cathode ray printer which is correctly adjusted. In order to minimize chaos in the sequence of vectors, the vertical strokes are recorded first and the horizontal strokes are recorded last. Directions are consistently from left to right and from top to bottom. This conforms more or less to the stroke sequence for hand drawn letters. A different sequence might improve the efficiency of a mechanical plotter by a reduction of the amount of motion in a pen up status.

The traditional origin of coordinates for digitalization would be on the base line of the character and at the left edge of the character block. The origin of coordinates for the alphabets at the Bell Telephone Laboratories is situated in the upper left corner of the character block. The origin of coordinates for the characters at the Naval Weapons Laboratory is situated centrally in the interior of the character. This simplifies the centering of isolated characters in cartographic applications and provides a common center line for mixtures* of fonts. Otherwise the origin is arbitrary and the data may be referred to any other origin by a relatively simple subroutine.

The digital data for each character are recorded in a separate block on tape. Each block consists of 16 decimal digit words. Each word is divided into four fields of four digits each. The first word is a beginning-of-block word and the last word is an end-of-block word. Each field of digital data is divided into two digit pairs. The first digit pair of the first field gives the left edge of the character block. The second digit pair of the first field gives the right edge of the character block. Each of the remaining fields give coordinates of a point. The first digit pair gives the X -coordinate and the second digit pair gives the Y -coordinate of the point.

*Examples of mixtures include large parentheses around built up fractions or Roman symbols in a Japanese text.

Negative coordinates are expressed by 9's complements. A vector is plotted between each successive pair of points. A field of 5000 signifies the end of a string of connected vectors. When this field is sensed, plotting is terminated at the last point and is resumed at the next point. A field of 5050 signifies the end of the character.

The raw data are not suitable for efficient machine computation. They must be reformatted in binary mode in such a way as to minimize the memory which is required to store them and to minimize the programming which is required to synthesize printer instructions from them. Although the synthesis of printer instructions could be done in FORTRAN, it is doubtful if this would be as efficient as a synthesis of printer instructions in machine language. STRAP routines are under development for conversion and extraction of data on STRETCH.

REPORT PREPARATION

The usual method for preparing reports at the Naval Weapons Laboratory consists in the typing of a manuscript with an ordinary typewriter which is fitted with Typits. The report herewith was prepared on a Varsityper. Six decisions must be made before a character can be struck. These are concerned with horizontal position, vertical position, character style, character size, keyboard bank, and typewriter key. The many errors which occur are painted over or are cut out and replaced laboriously with corrective patches. The alternative would be the typing of the report on a paper or magnetic tape, which could be rewritten and corrected as many times as necessary. Once a correct tape has been achieved, all further conversion and printing becomes automatic. Writing on tape has the disadvantage that the typist must be trained to use function codes. All coding should be mnemonic or phonetic as far as possible without undue complication.

DISCUSSION

The effective utilization of a large repertory depends upon the development of an adequate mnemonic code which a typist can be trained to use. Experimental codes have been described by Barnett⁸⁶. Certainly the alphabetic characters will serve as input to Roman alphabets. There is available a convenient transliteration of Greek into Roman for mathematical applications. This transliteration is more nearly isomorphic than isophonic. The phonetic transliterations of Greek, Russian, and Japanese should serve for linguistic applications.

The primary criterion for a choice between character designs is based on what looks best. Attempts to apply mathematical rules have not been entirely adequate. The ultimate criterion certainly is subjective and is an aspect of gestalt psychology. The end of a line seems to have less importance geometrically than it has psychologically. The apparent interaction between a character and the environment in which it is situated may be an application of the adjacency principle of Gogel⁸⁷.

CONCLUSION

It can be concluded that the preparation of mathematical reports is almost within the reach of the latest cathode ray printer equipment.

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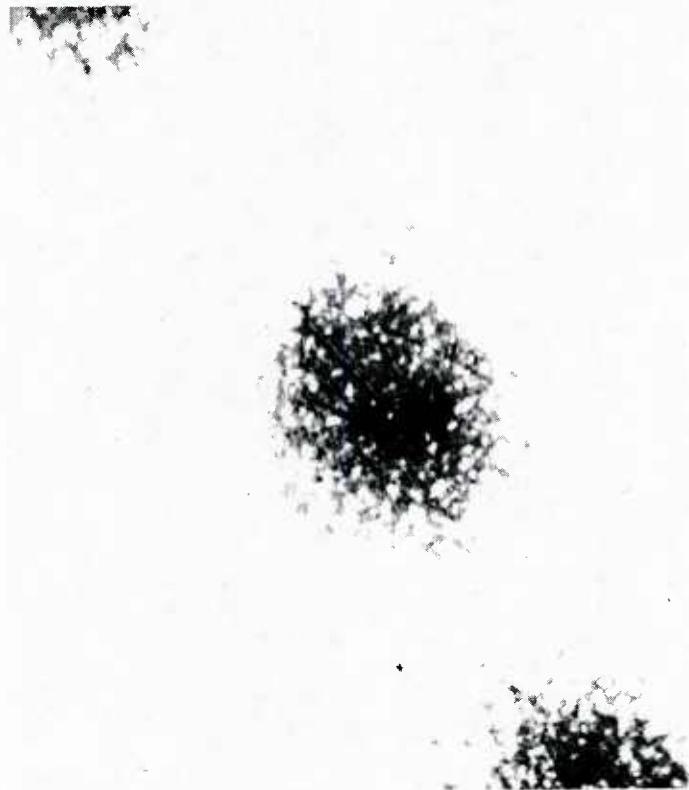


FIGURE 1.

Photomicrograph at 650 magnification of dot plotted by NORC
S-C 4010 Printer on 35 mm Recordak Dacomatic Safety Film.

APPENDIX A

DIGITALIZATION WITH DOTS

In each panel, the coordinates of each dot are plotted at enlarged scale on the left, the character and its number are plotted at normal scale in the upper right, and the digit pairs are listed at the right.

PART I

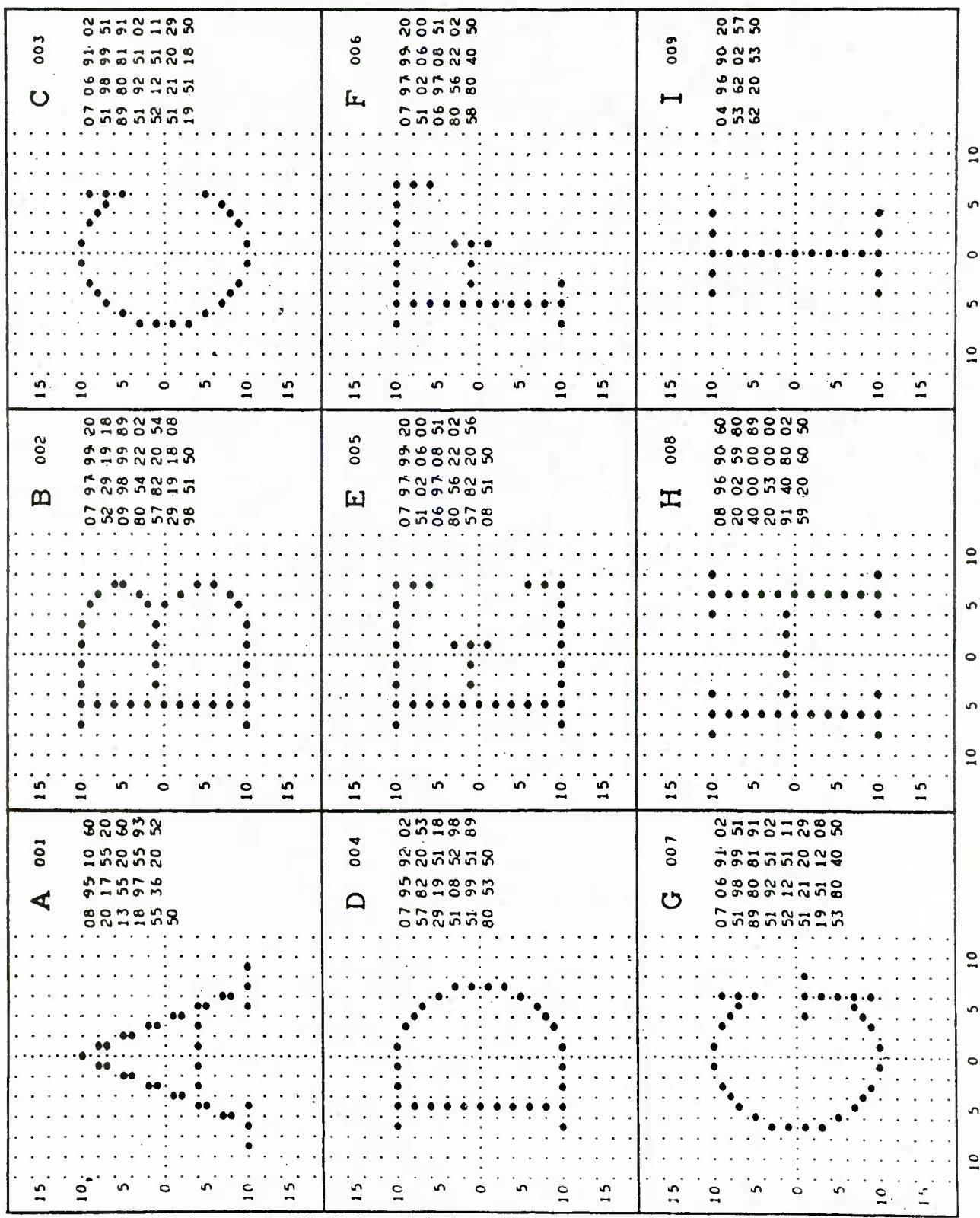
MATHEMATICAL REPERTORY

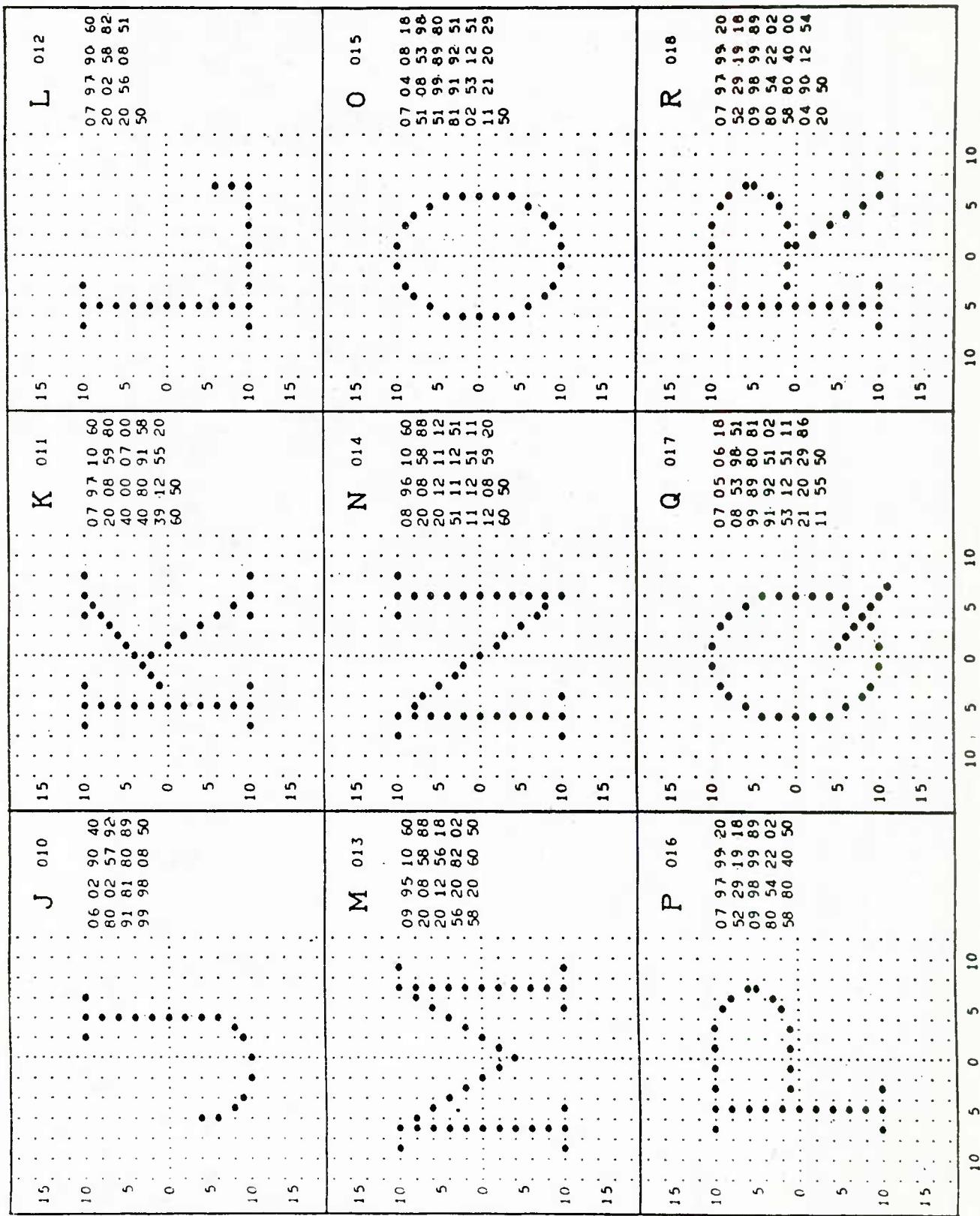
STRETCH SUBROUTINE TO EXTRACT CHARACTER DATA FROM BLOCK 0130

SUBROUTINE XCD130 (NC, IC)

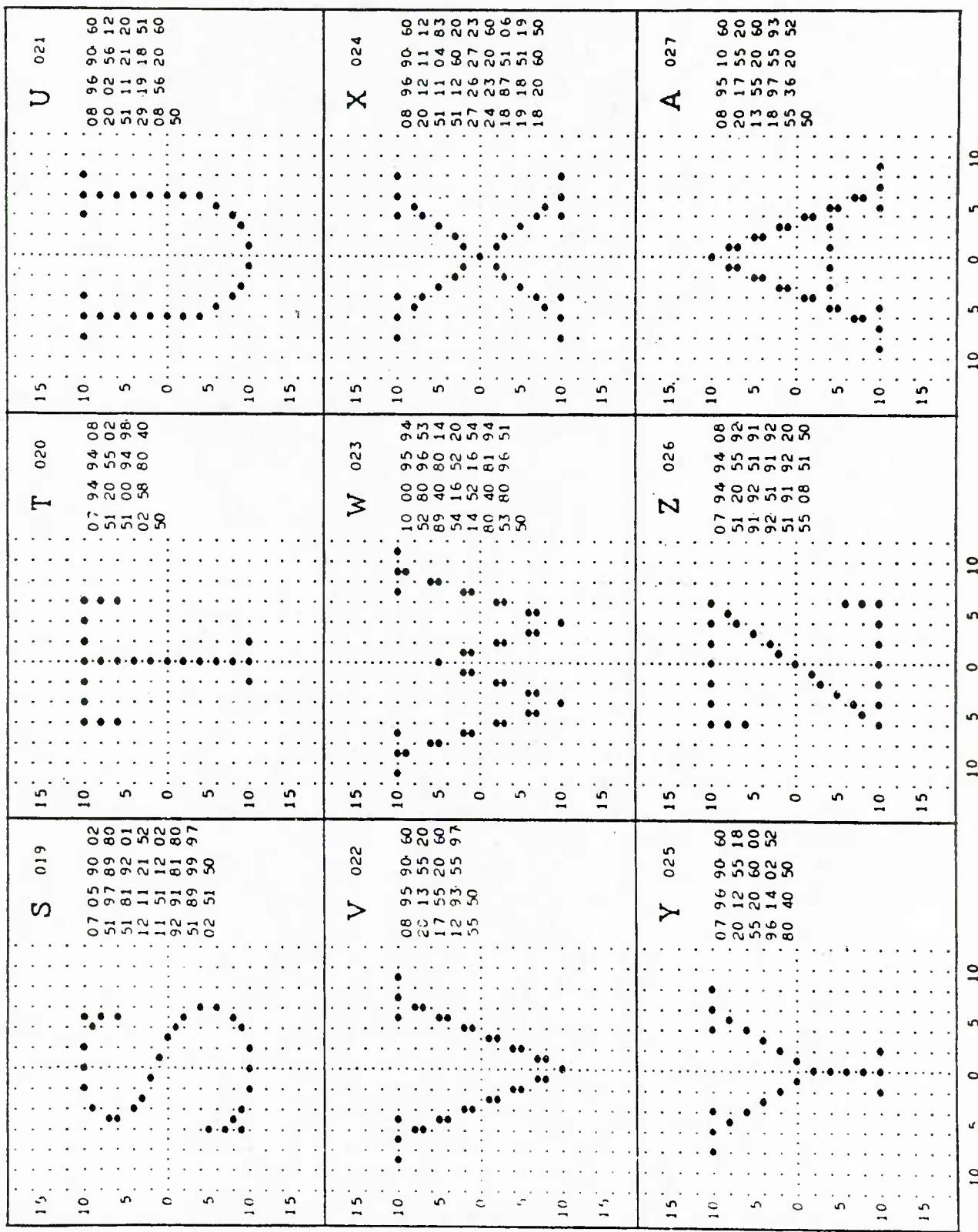
NC = CHARACTER NUMBER (FORTRAN INTEGER)

IC = CHARACTER ARRAY (SYMBOLIC ADDRESS)

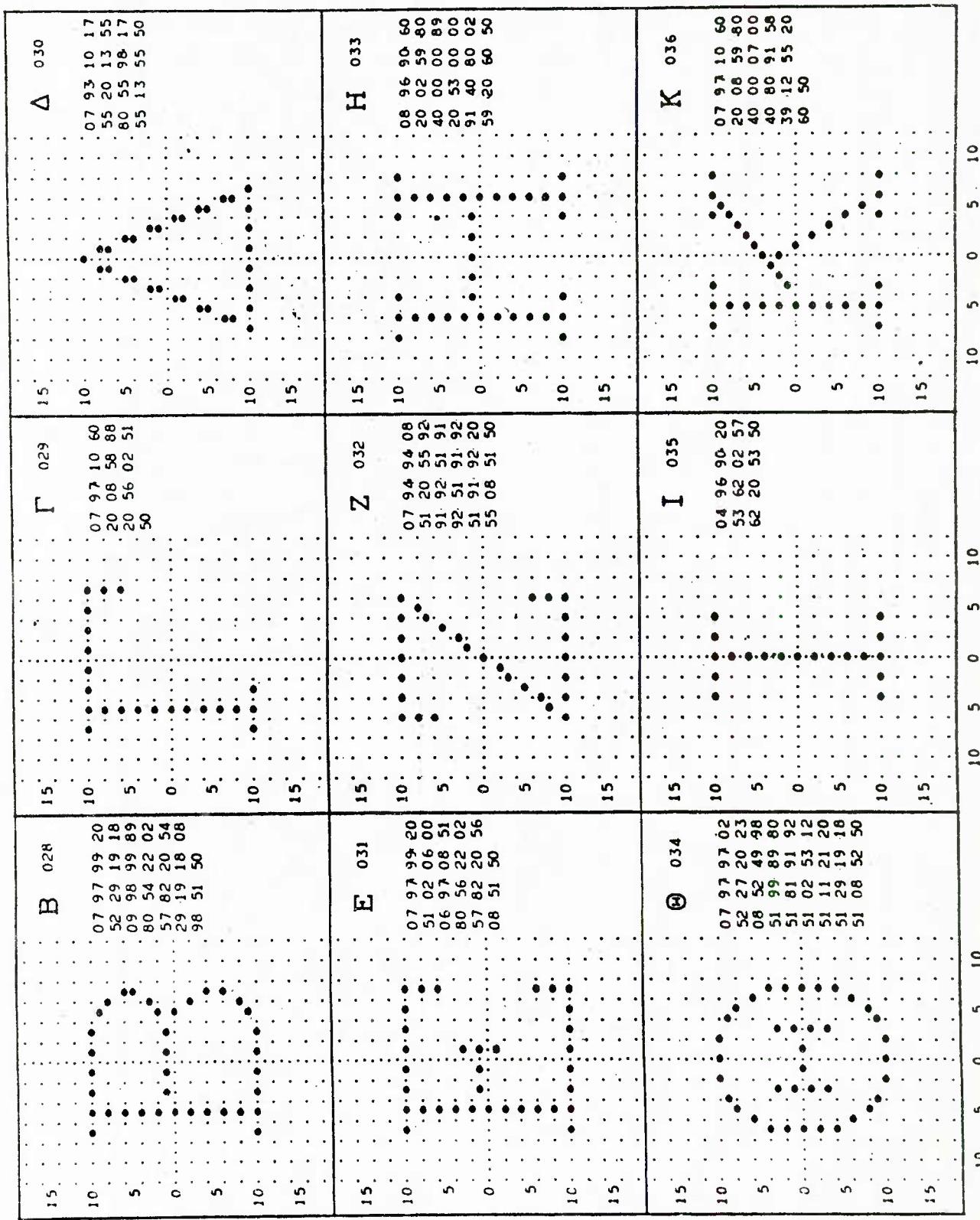




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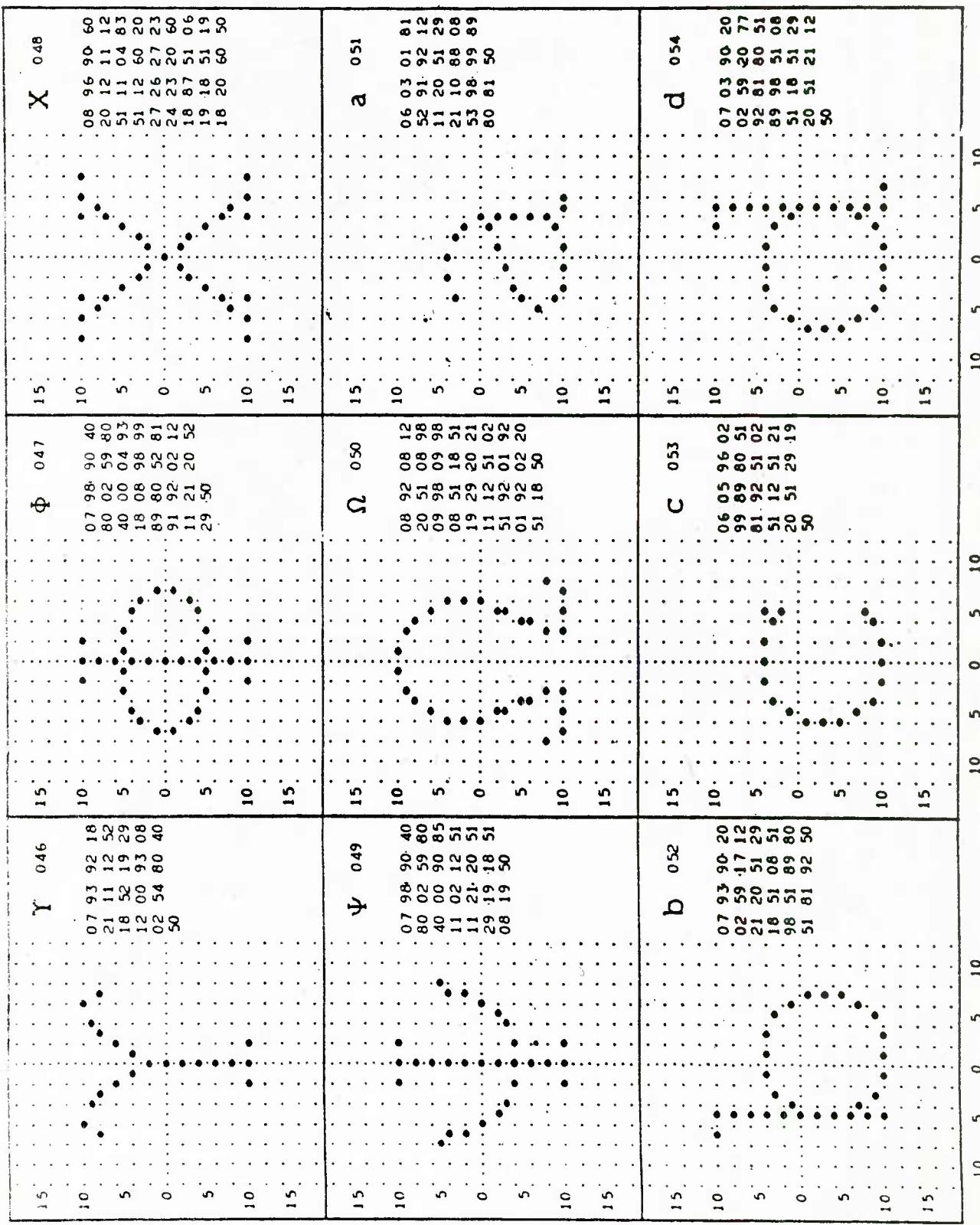


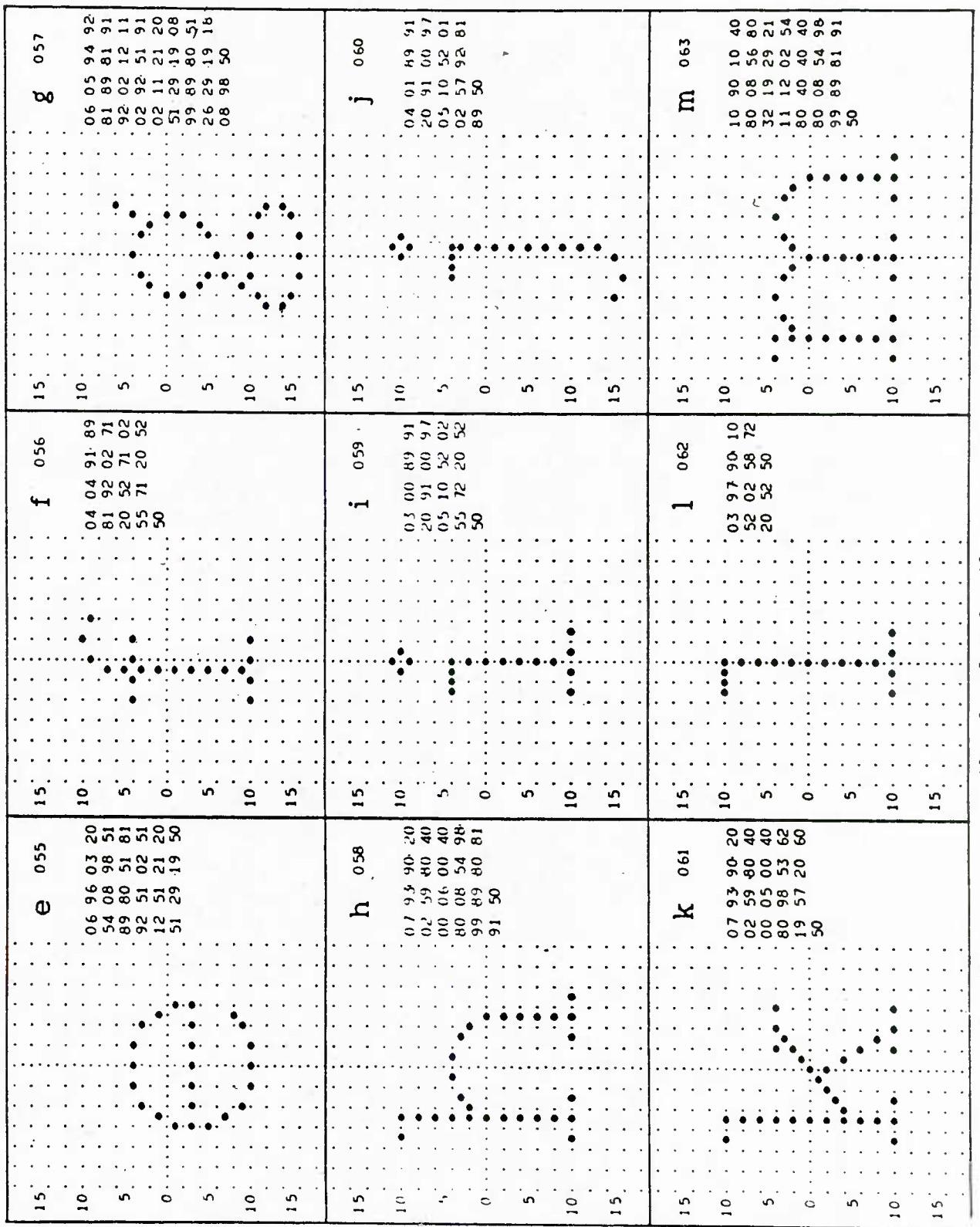
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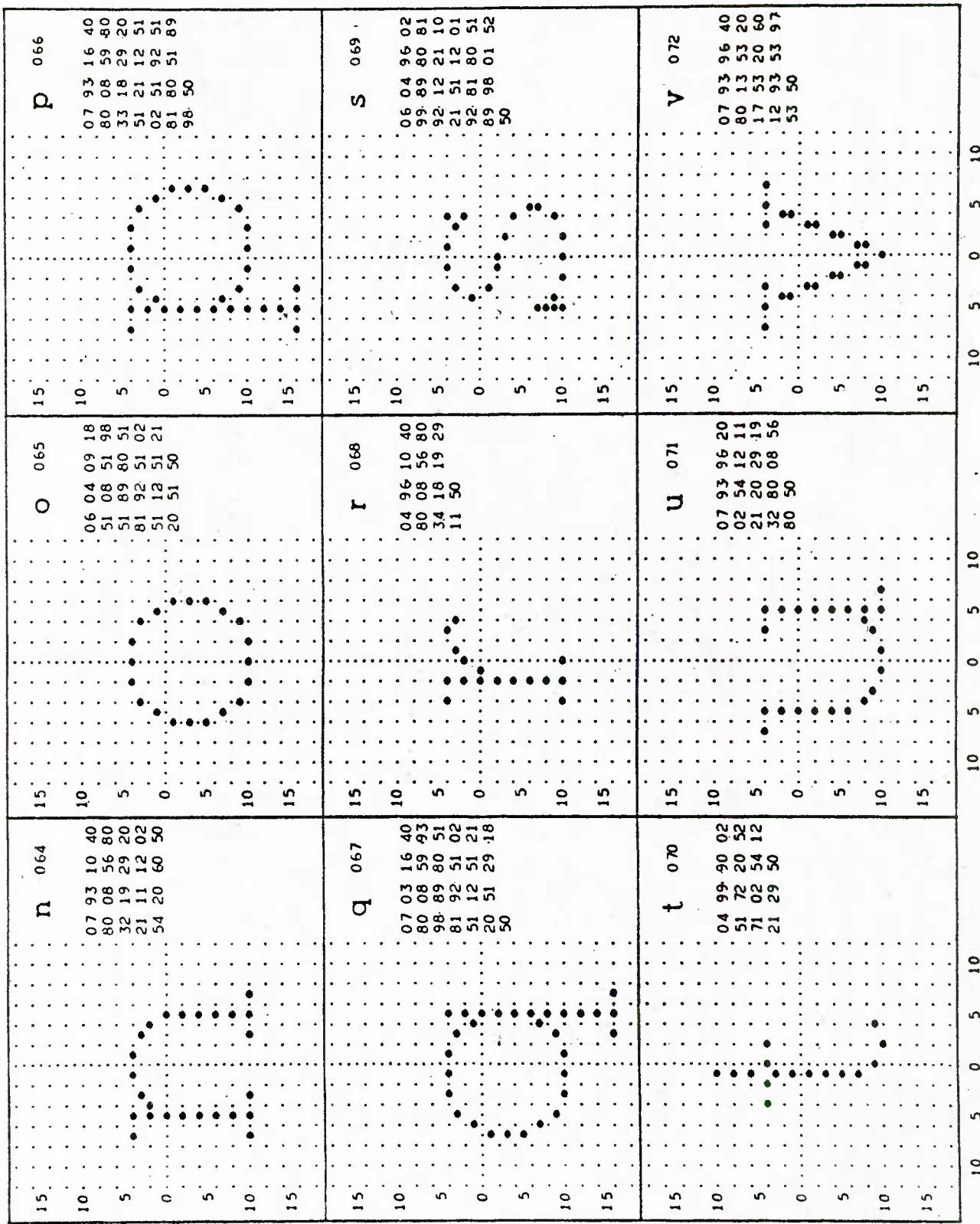


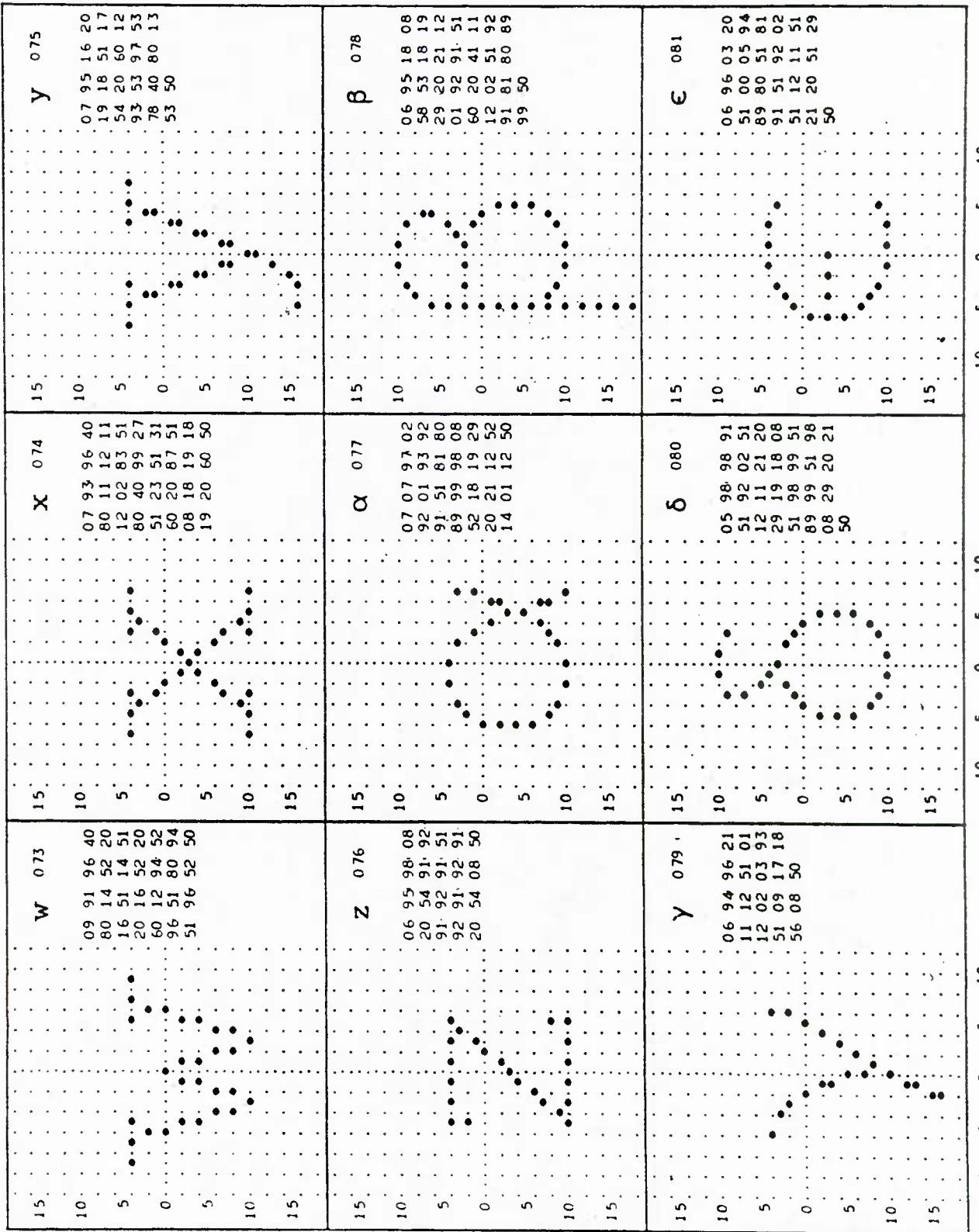
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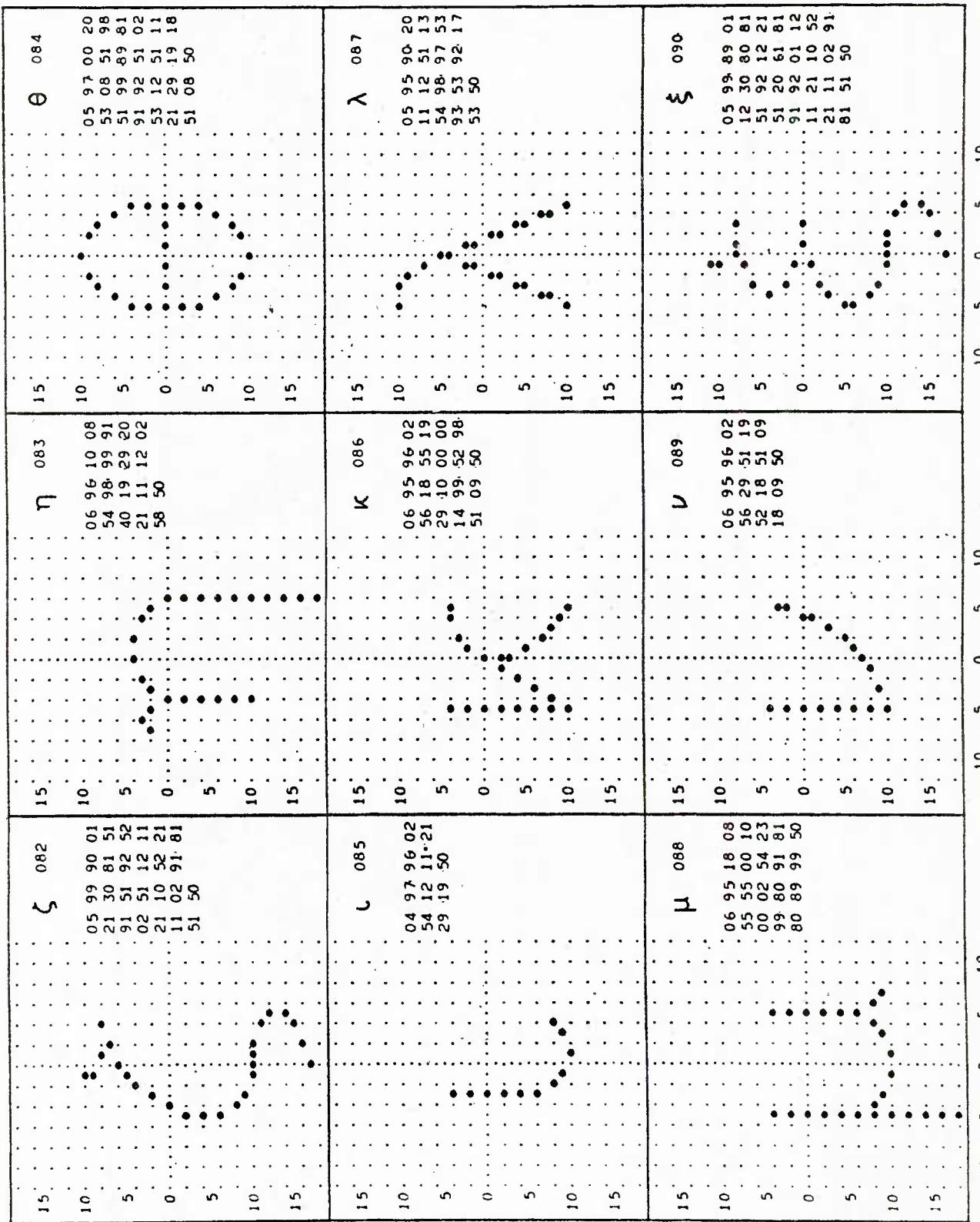
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		A 037	15		M 038	15		N 039	15		Π 042	15		T 045	15	10 5 0 5 10
		08 95 10 60	10		09 95 10 60	10		08 96 10 60	10		08 96 10 60	10		07 94 94 08	10	10 5 0 5 10
15		20 17 55 20			20 08 58 08			20 08 58 08			20 08 58 08			51 20 55 02		10 5 0 5 10
10		13 55 20 60	5		20 12 56 18	5		20 12 56 18	5		20 12 56 18	5		51 11 51 12		10 5 0 5 10
5		18 97 55 93			56 20 82 02			56 20 82 02			56 20 82 02			51 11 51 12		10 5 0 5 10
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15														60 50		10 5 0 5 10
		H 040			O 041			Π 042			T 045			10 5 0 5 10		
		07 93 11 08	10		07 07 96 98	10		08 96 10 60	10		08 96 10 60	10		07 94 94 08	10	10 5 0 5 10
15		52 23 20 54			51 99 89 80			20 08 58 08			20 08 58 08			51 20 55 02		10 5 0 5 10
10		23 08 52 78	5		51 81 91 92	5		20 57 62 02			20 57 62 02			51 11 51 12		10 5 0 5 10
5		08 52 63 80			51 02 53 12			58 20 60 50			58 20 60 50			51 11 51 20		10 5 0 5 10
0		51 83 08 52	0		51 29 19 18	0		51 29 19 18	0		51 29 19 18	0		51 00 94 96		10 5 0 5 10
		78 08 32 23			51 08 52 50			51 08 52 50			51 08 52 50			02 58 80 40		10 5 0 5 10
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		P 043			Σ 044			T 045			10 5 0 5 10			10 5 0 5 10		
		07 97 99 20	10		07 06 94 98	10		07 94 94 08	10		07 94 94 08	10		07 94 94 08	10	10 5 0 5 10
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10		09 98 99 89	5		54 92 54 20	5		51 00 94 96			51 00 94 96			51 00 94 96		10 5 0 5 10
5		80 54 22 02			54 18 51 50			02 58 80 40			02 58 80 40			02 58 80 40		10 5 0 5 10
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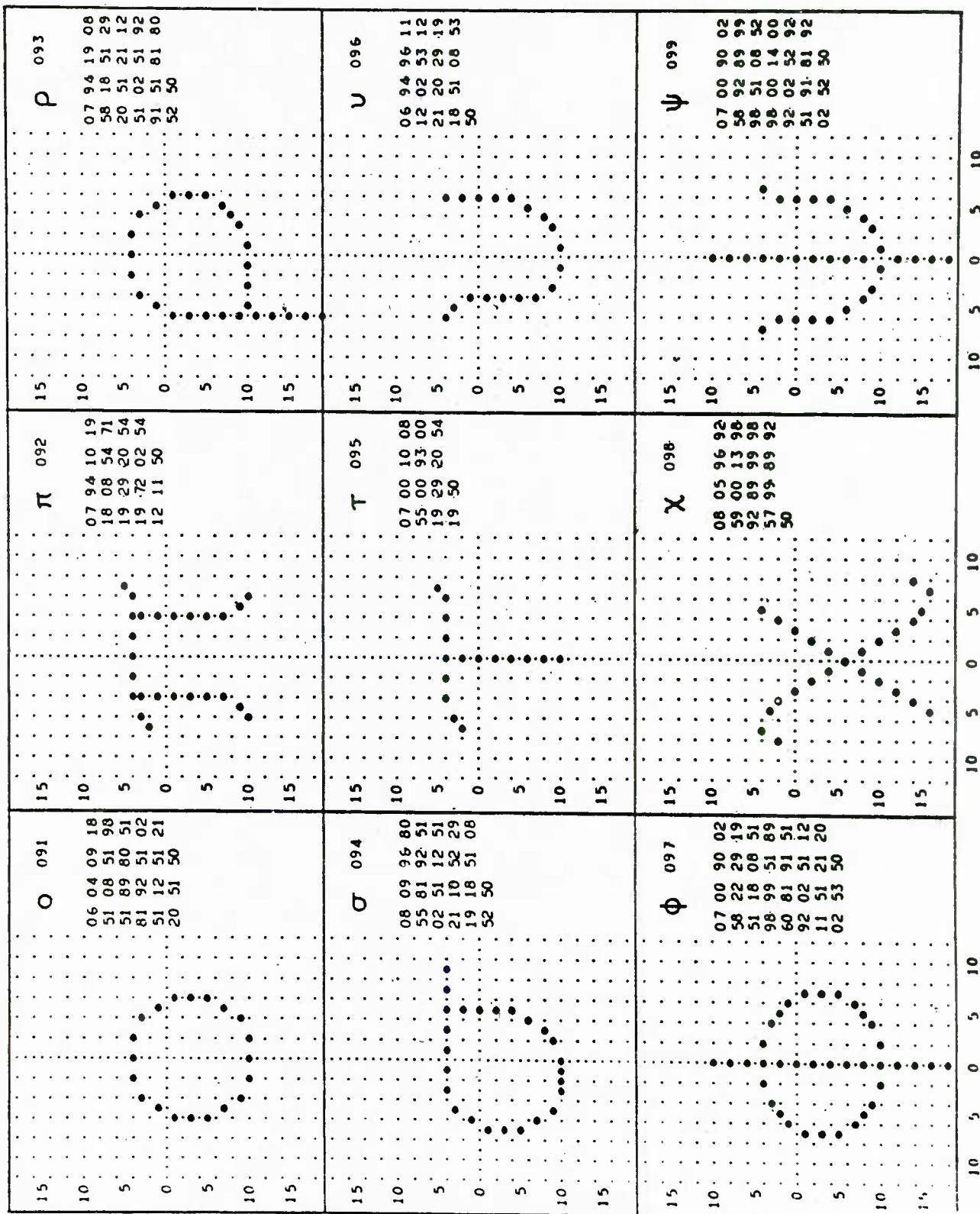


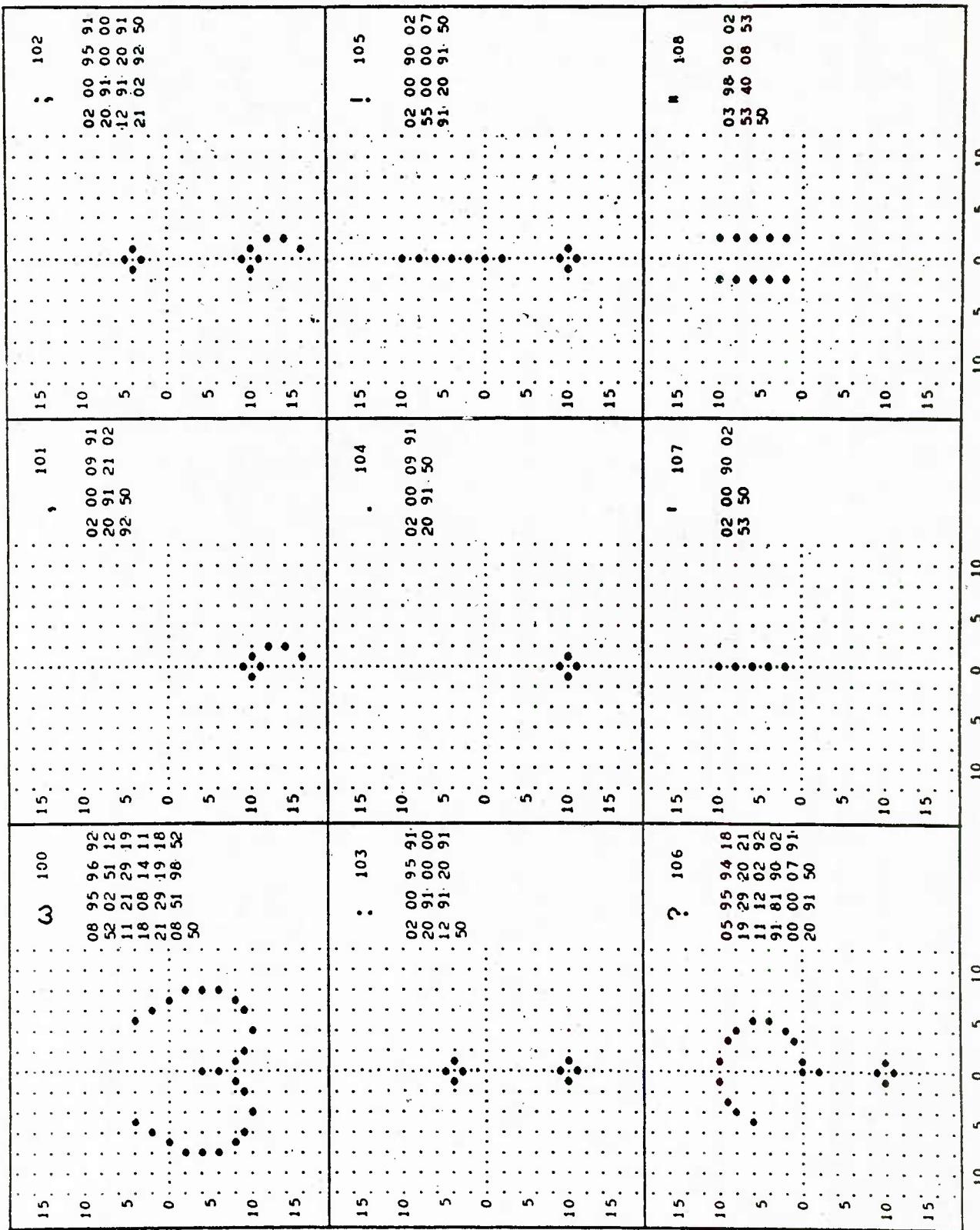




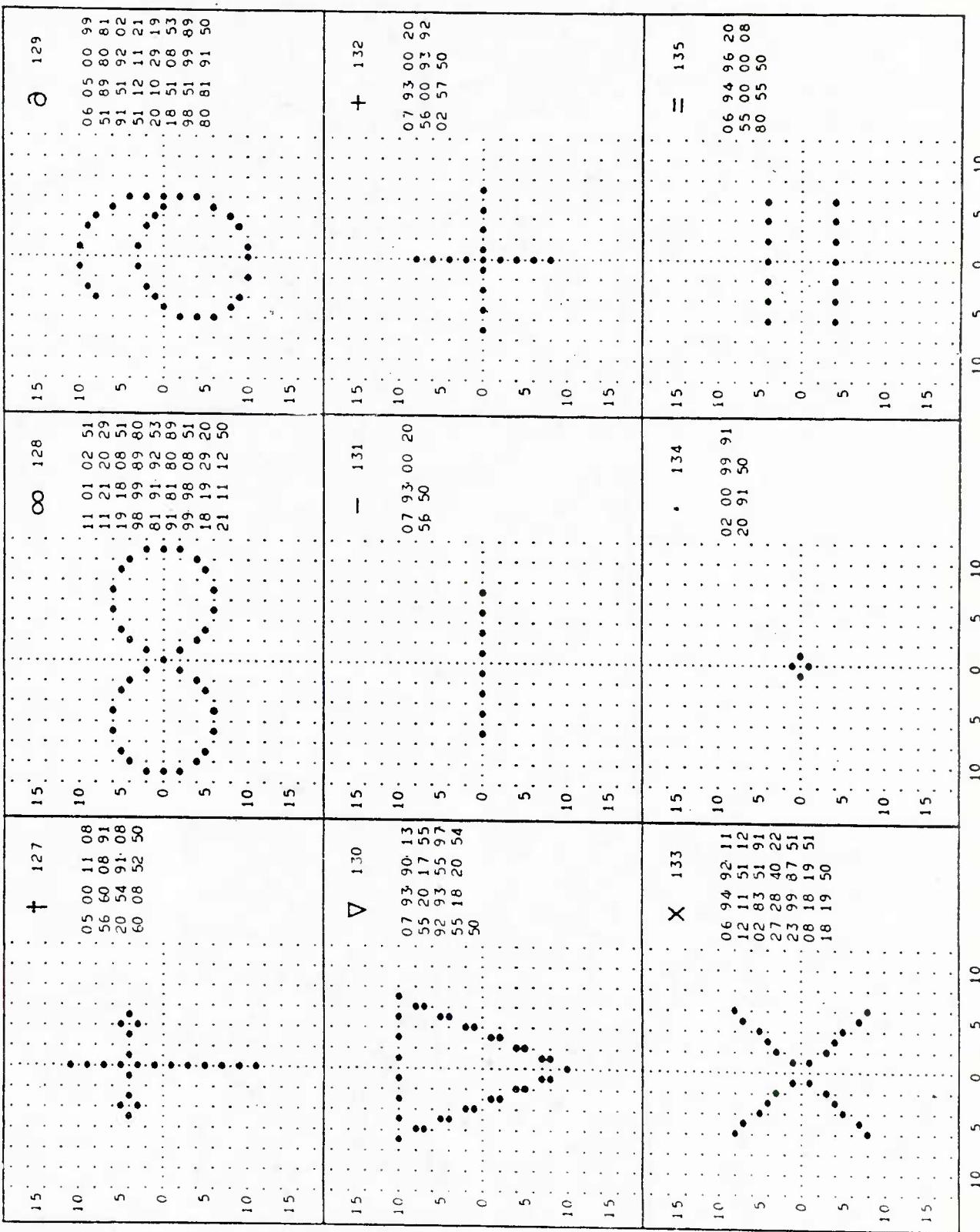


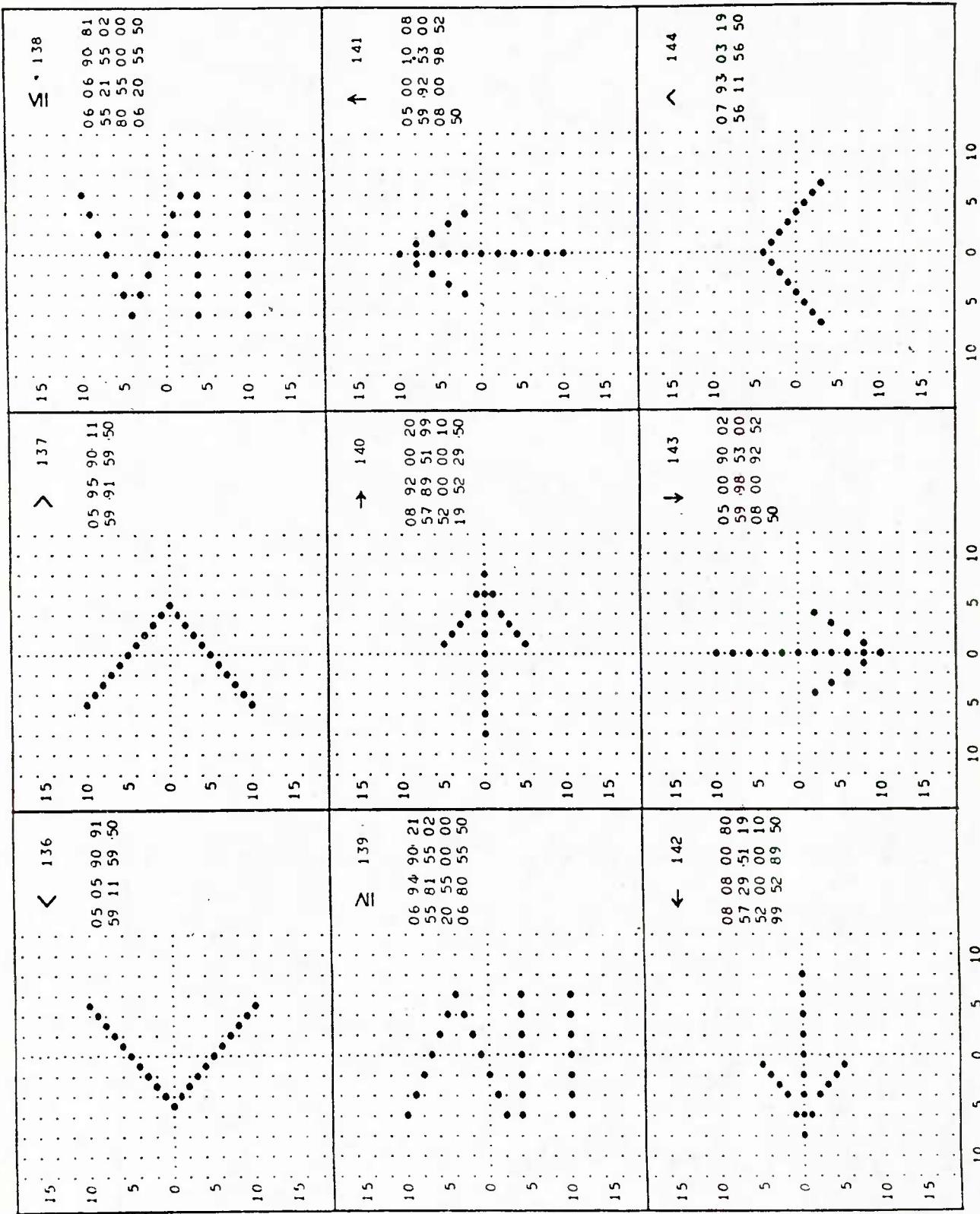
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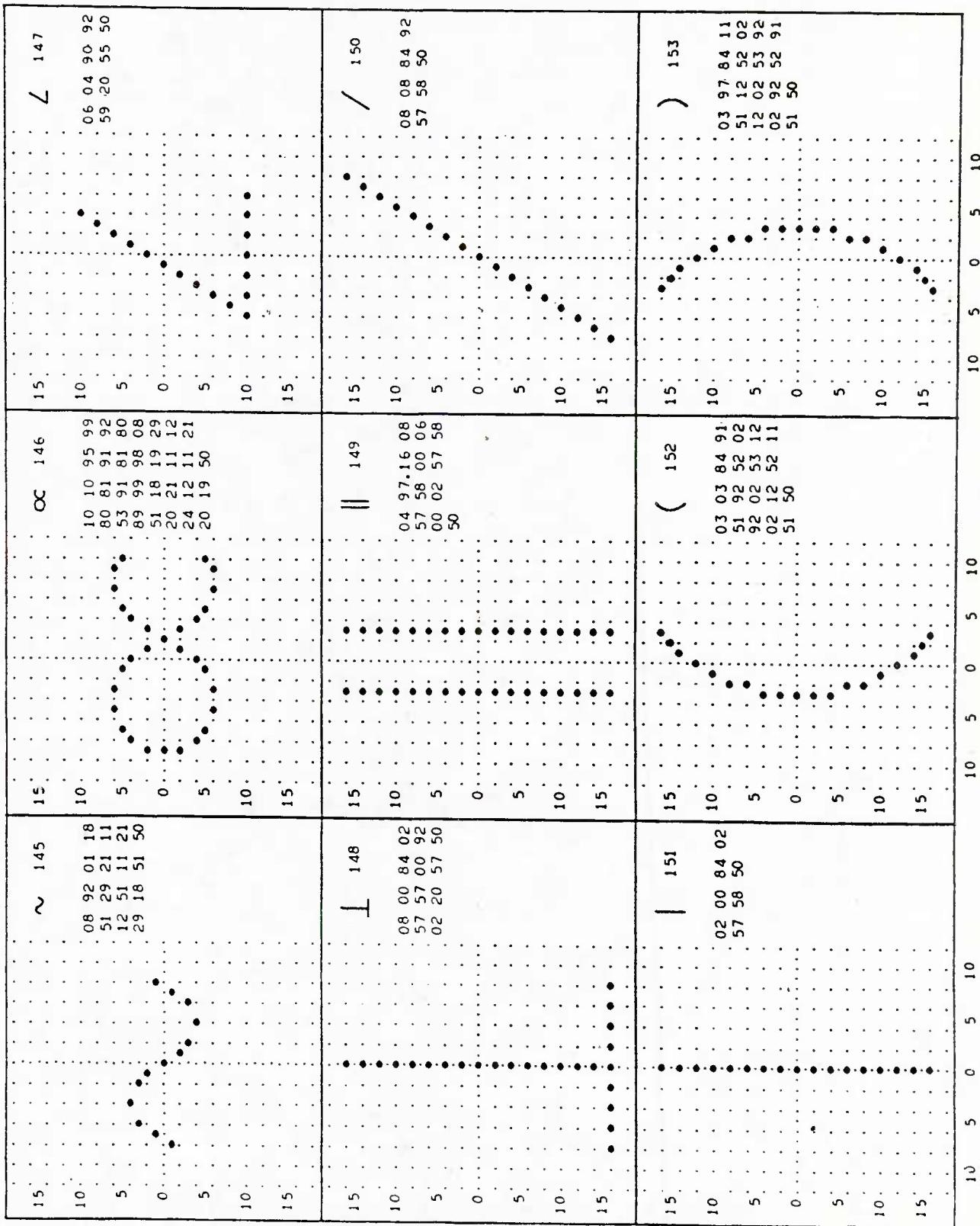


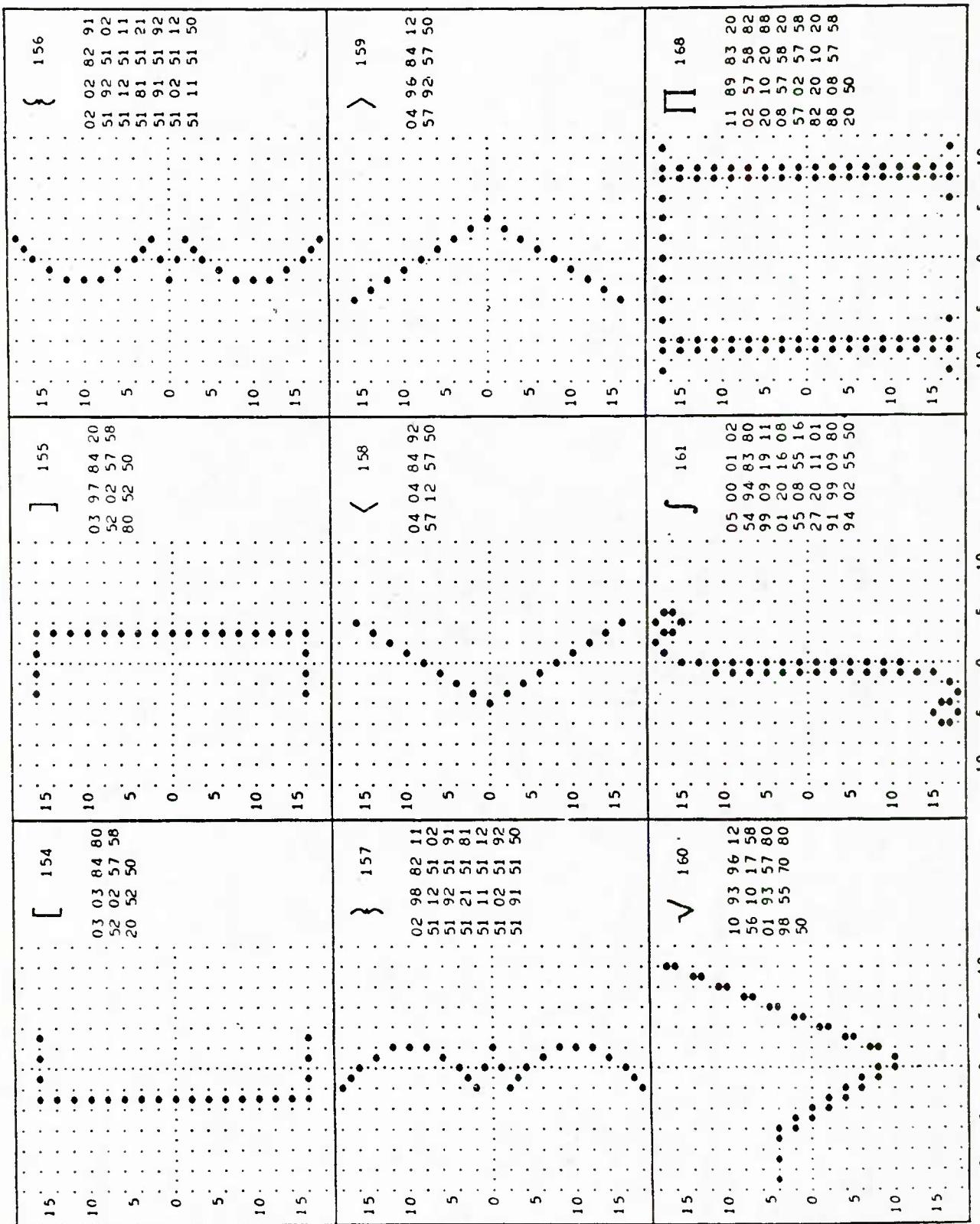
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15	15	06 95 94 18	10		06 95 94 08	10		06 07 04 80			06 07 04 80		
10	10	19 29 20 21			51 20 54 01			56 36 52 91			56 36 52 91		
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0	0	91 81 52 91			21 11 12 02			52 02 59 80			52 02 59 80		
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5	5	29 20 51 21	5		11 12 02 51	5		59 50			59 50		
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0	0												
10	10												
5	5												
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10	10												
5	5												
0	0			</td									

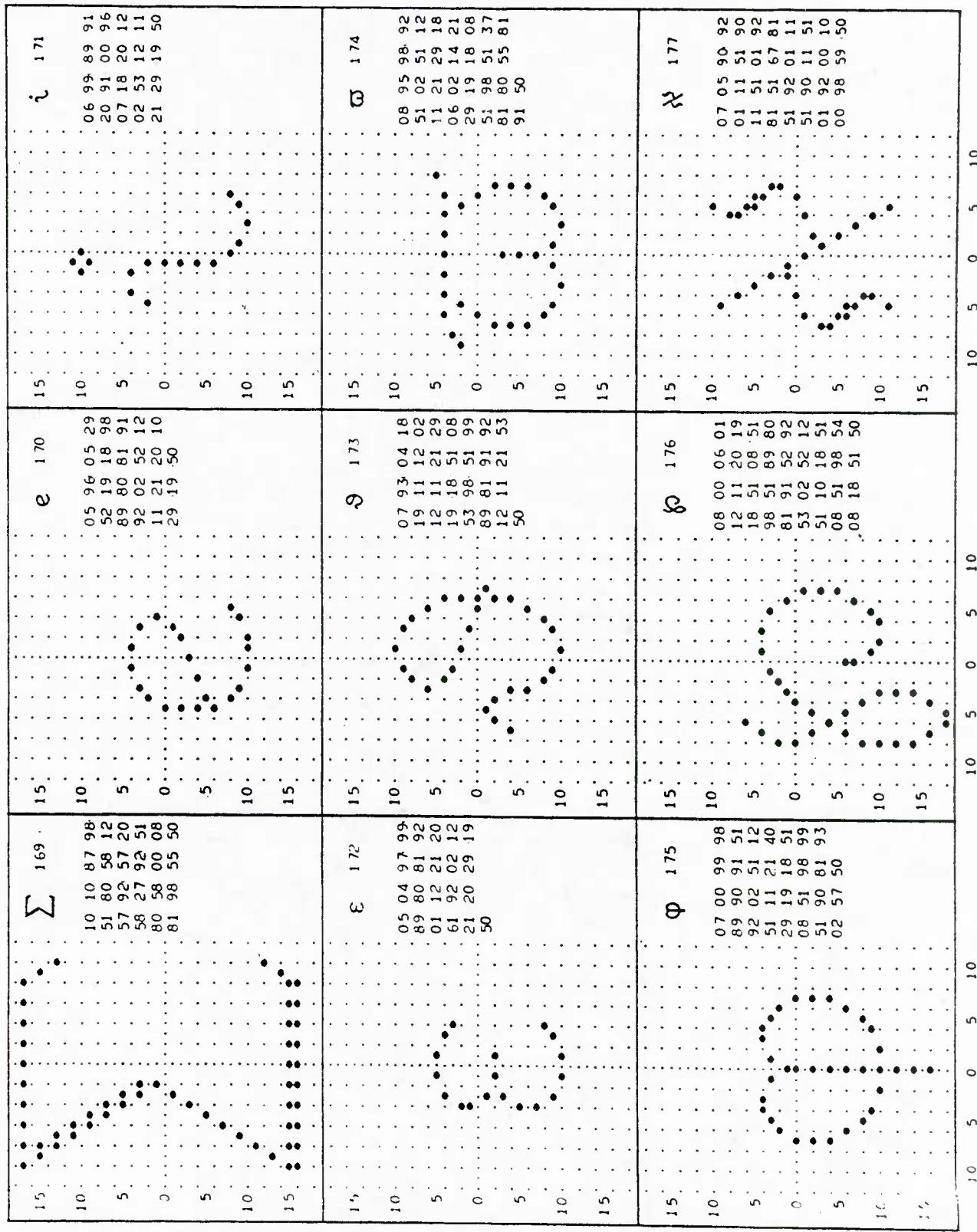


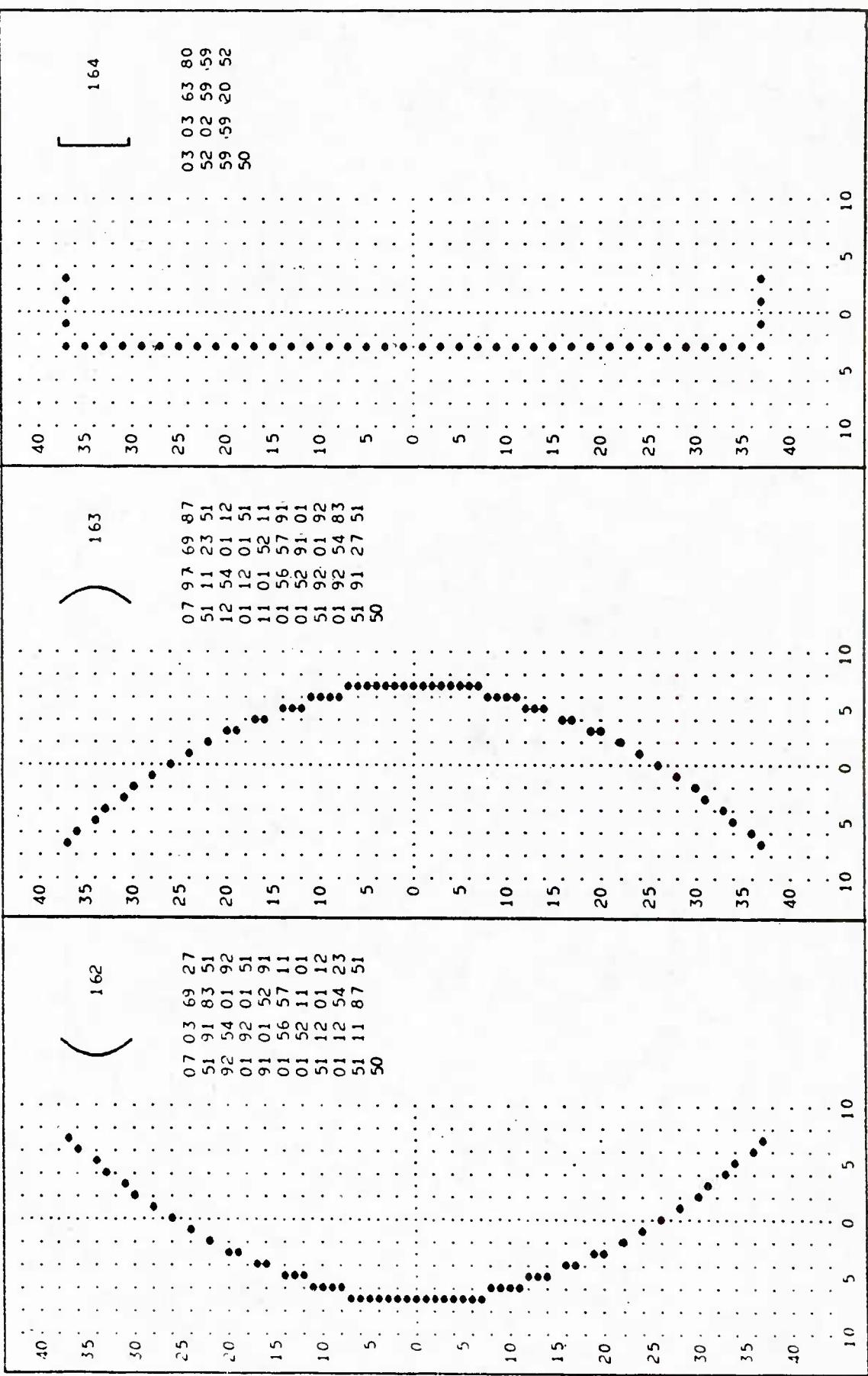


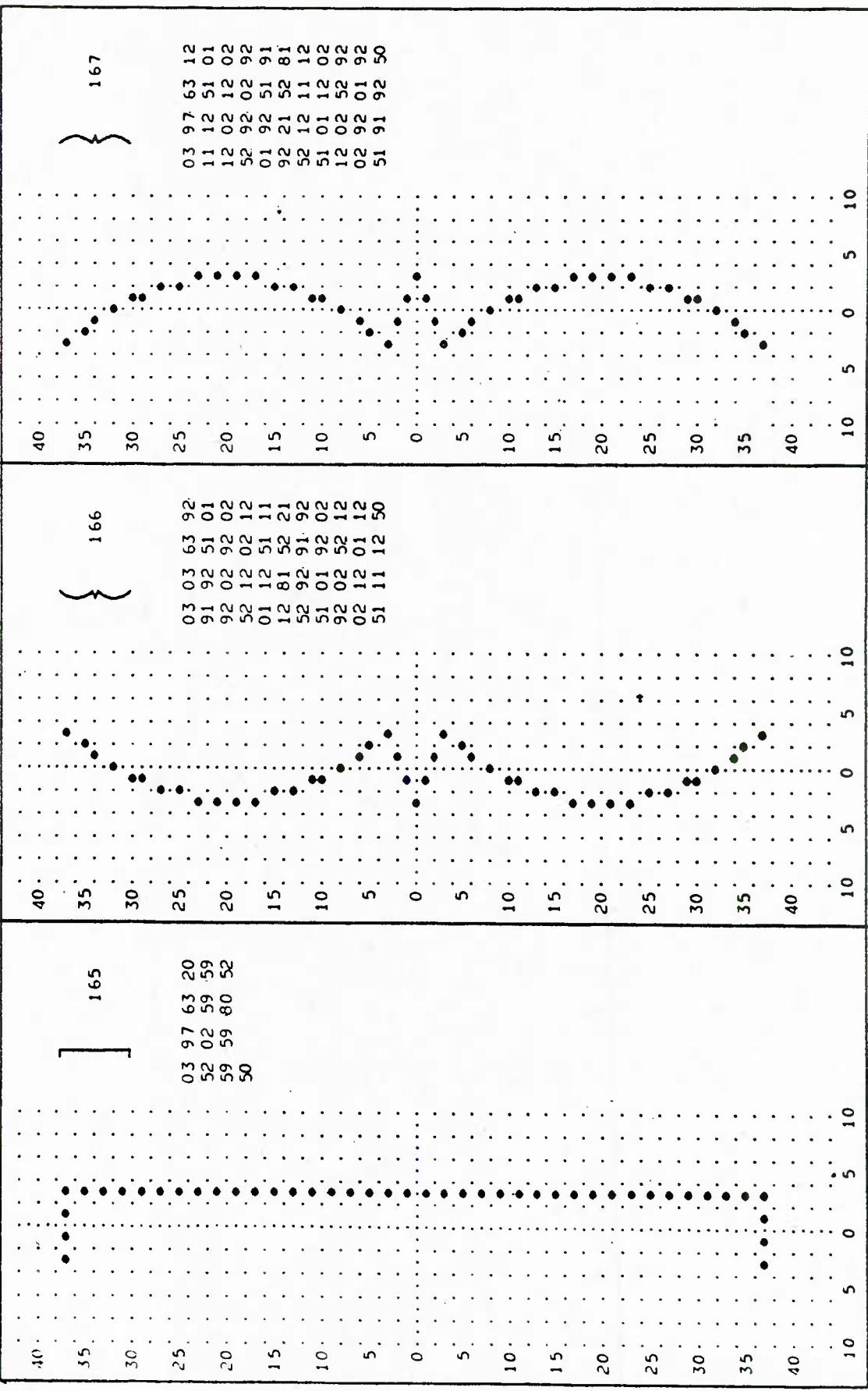
10 5 0 5 10 10 5 0 5 10 10 5 0 5 10











PART II

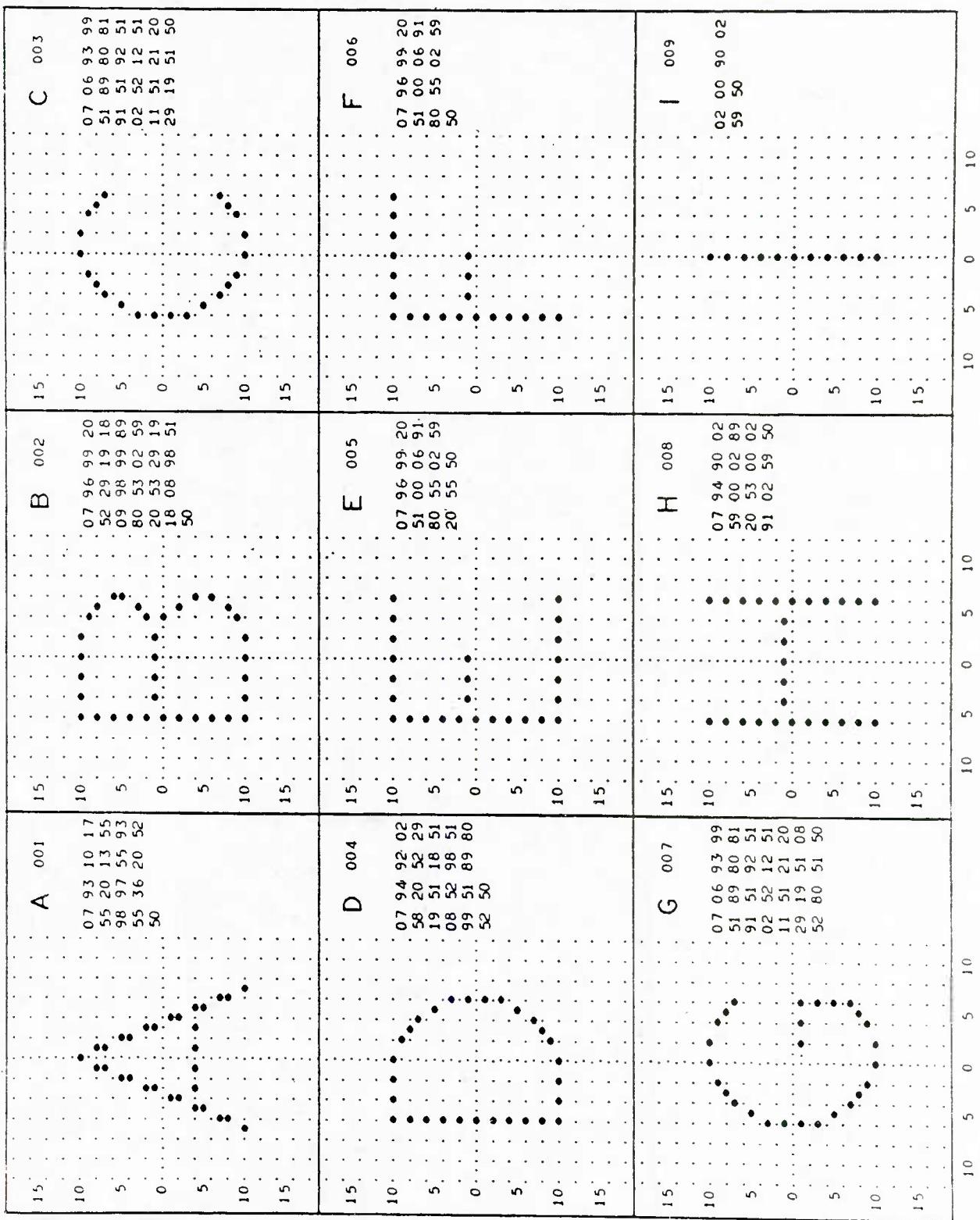
CARTOGRAPHIC REPERTORY

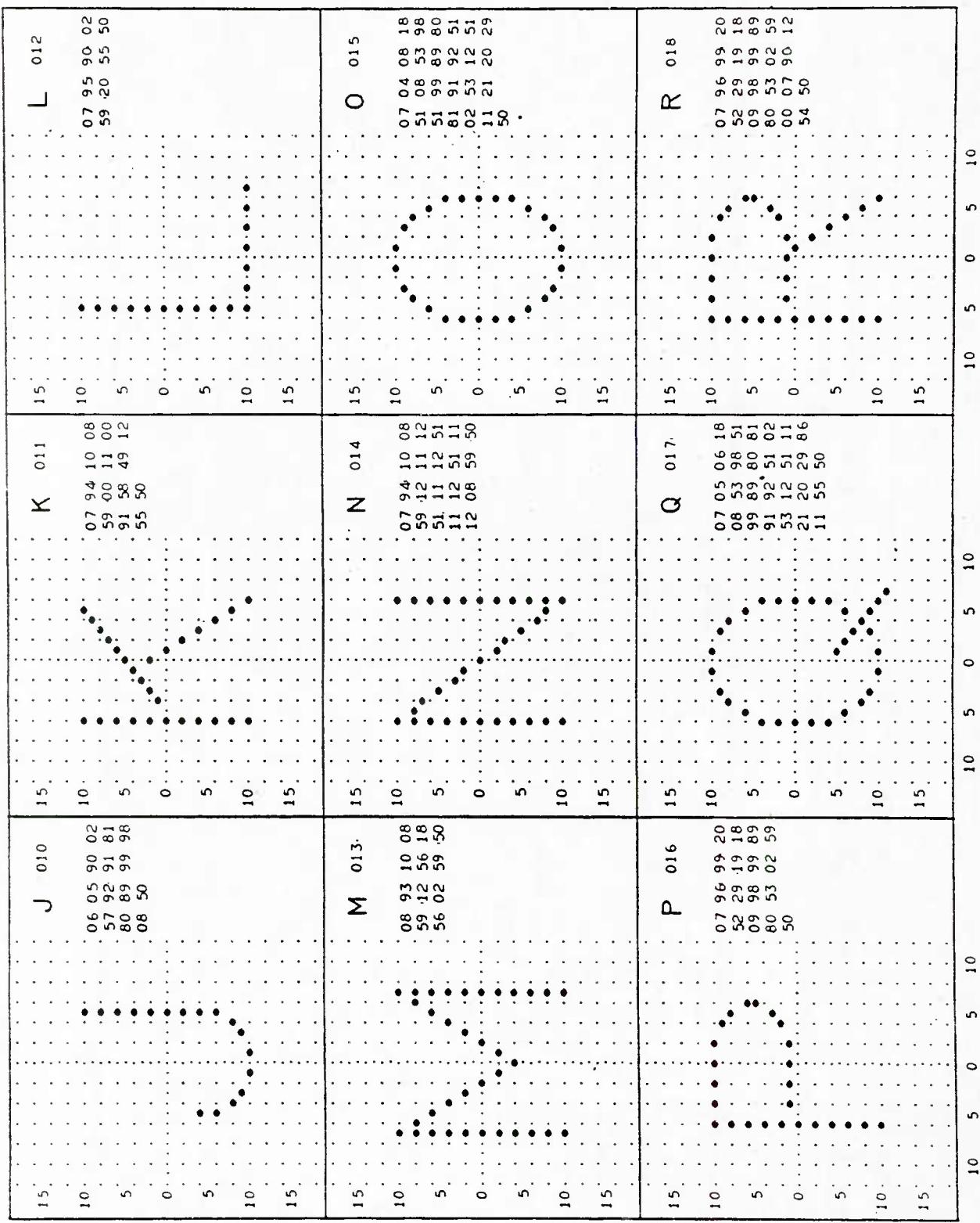
STRETCH SUBROUTINE TO EXTRACT CHARACTER DATA FROM BLOCK 0160

SUBROUTINE XCD160 (NC, IC)

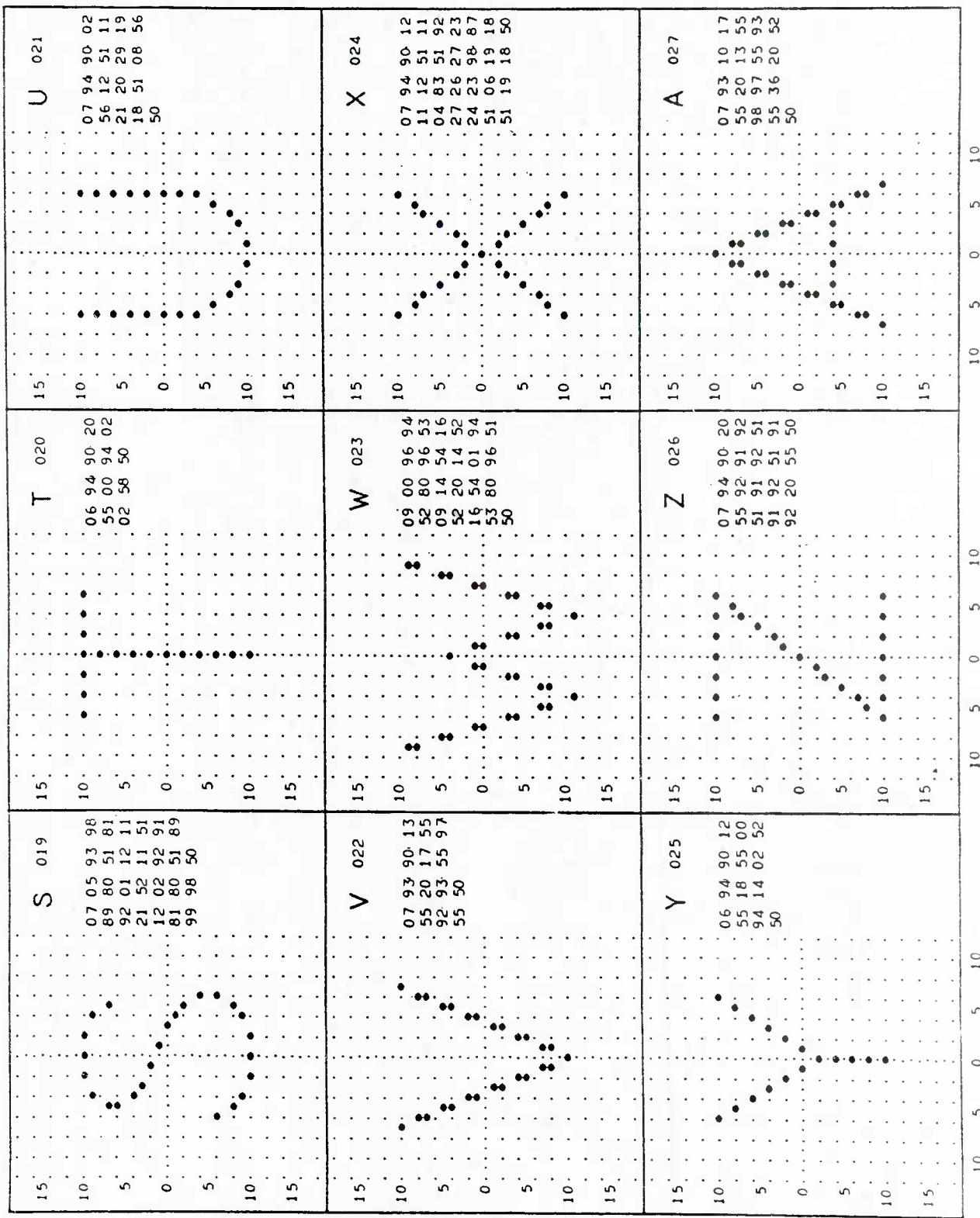
NC = CHARACTER NUMBER (FORTRAN INTEGER)

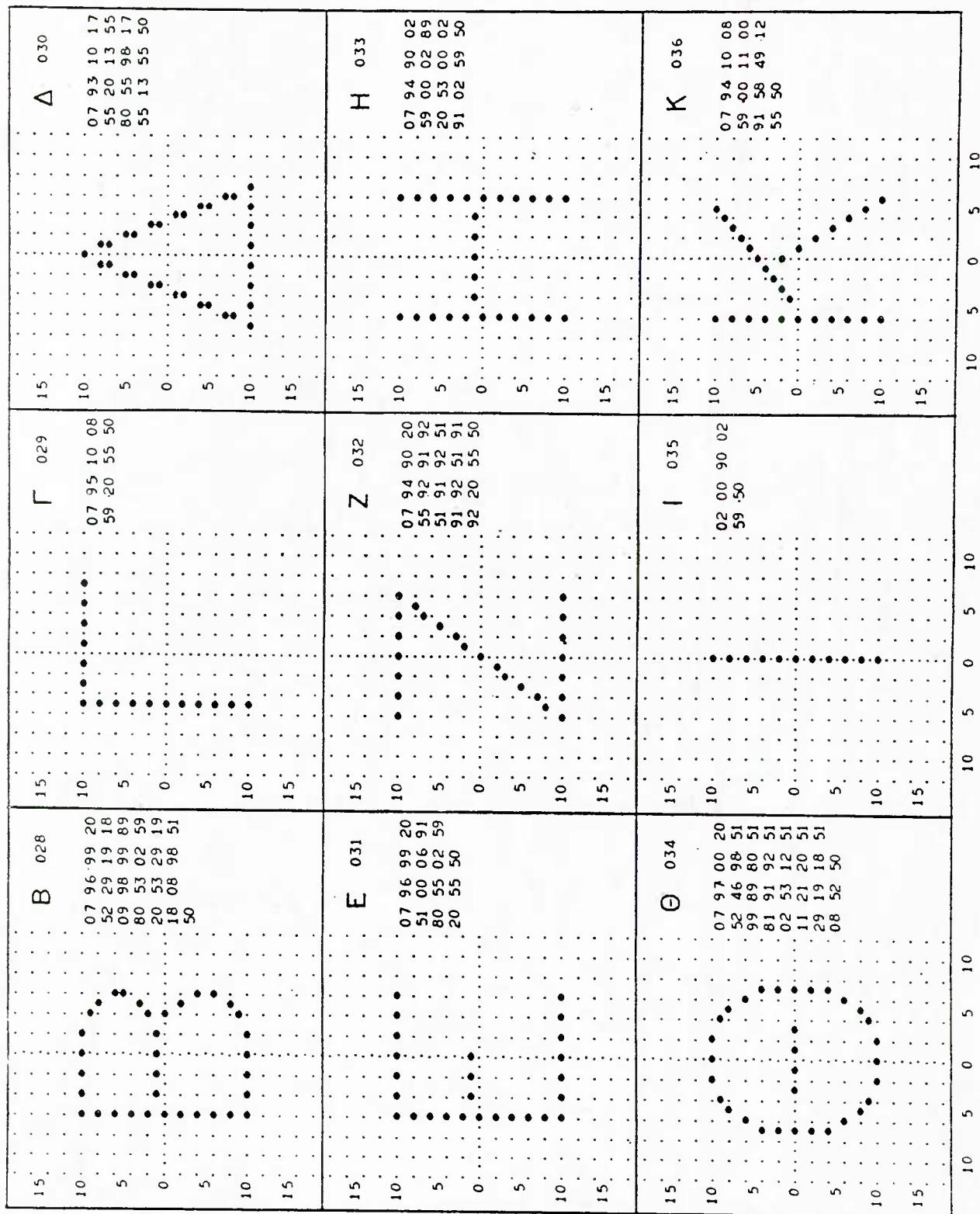
IC = CHARACTER ARRAY (SYMBOLIC ADDRESS)



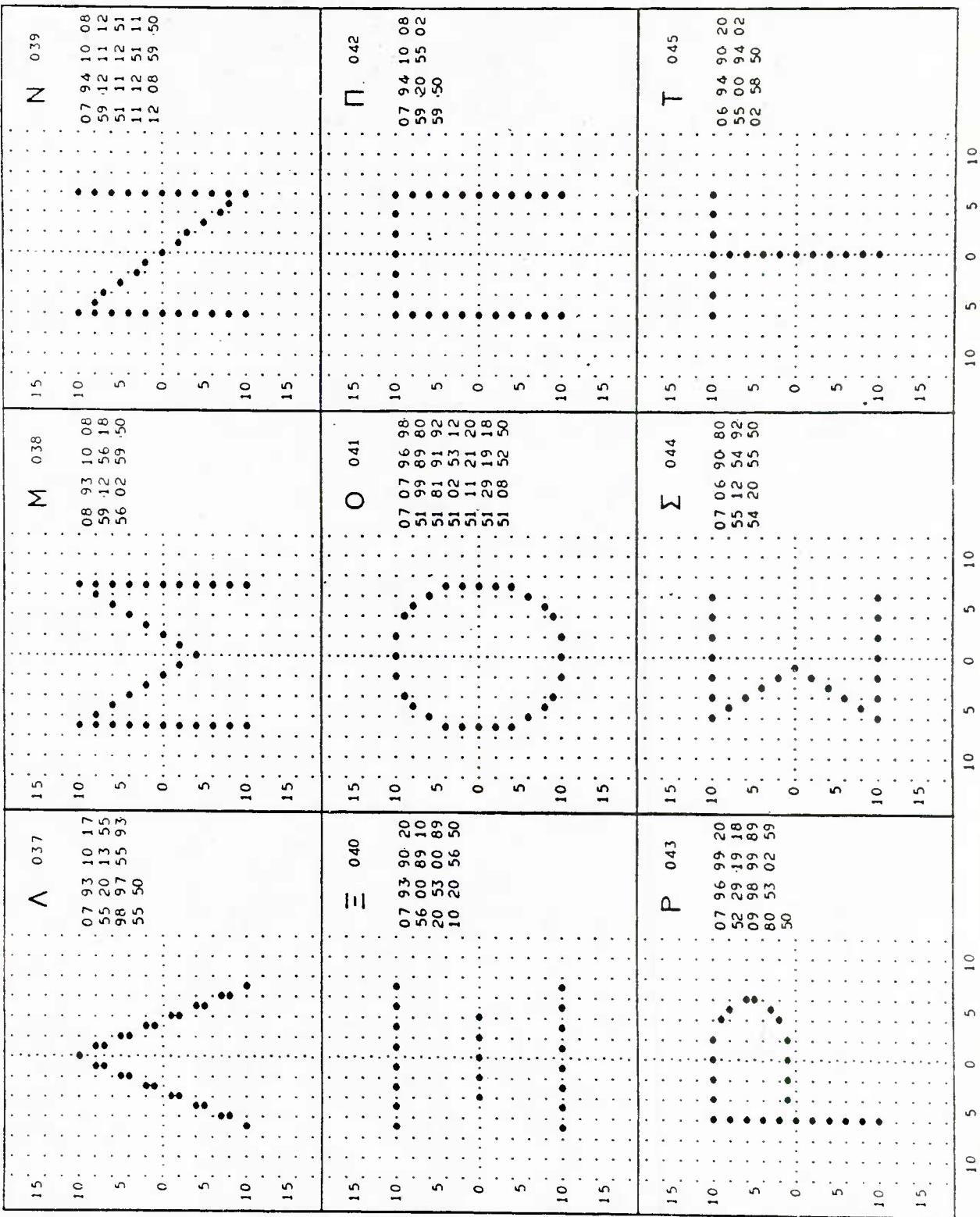


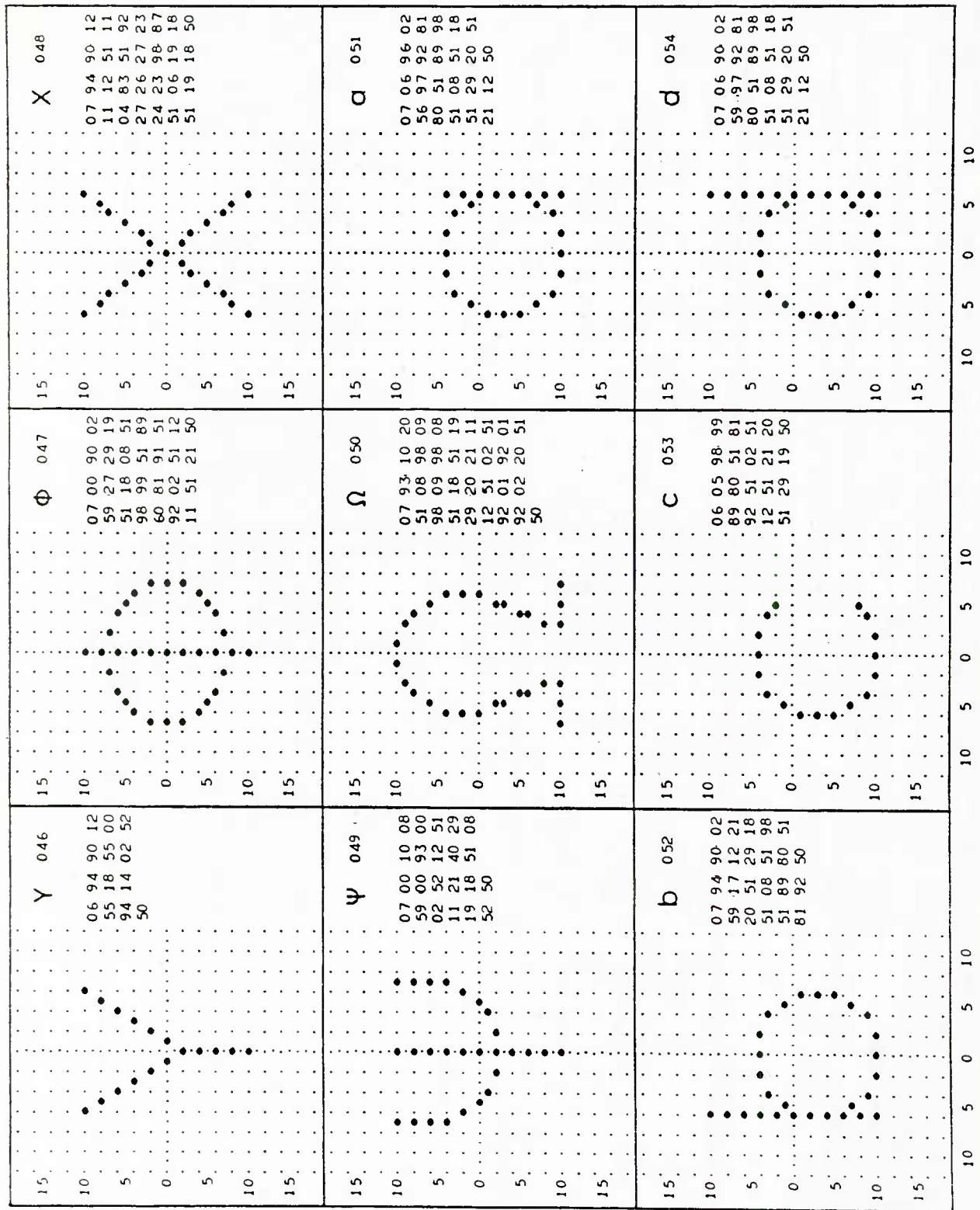
10 5 0 5 10 10 5 0 5 10 10 5 0 5 10



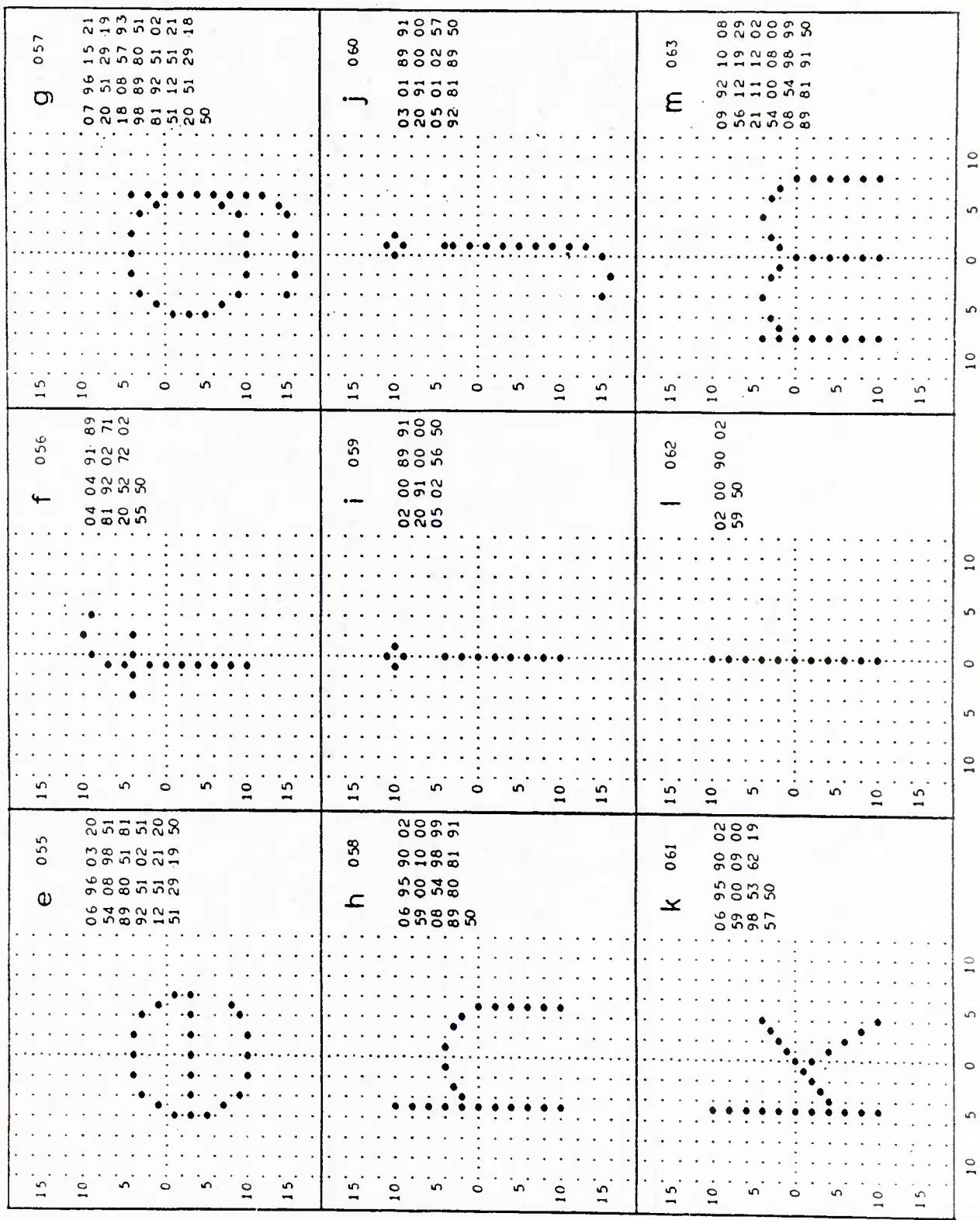


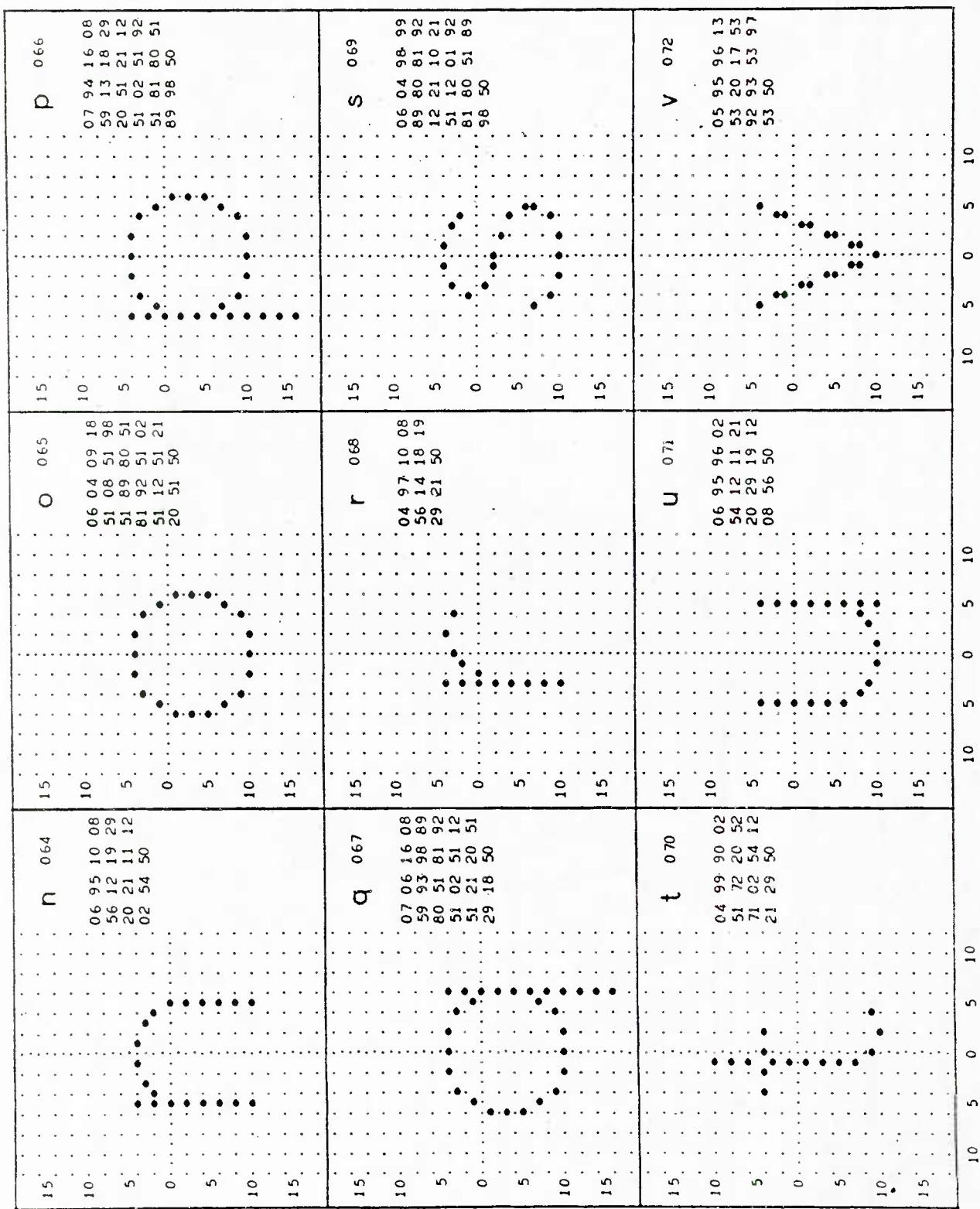
10 5 0 5 10 10 5 0 5 10 10 5 0 5 10

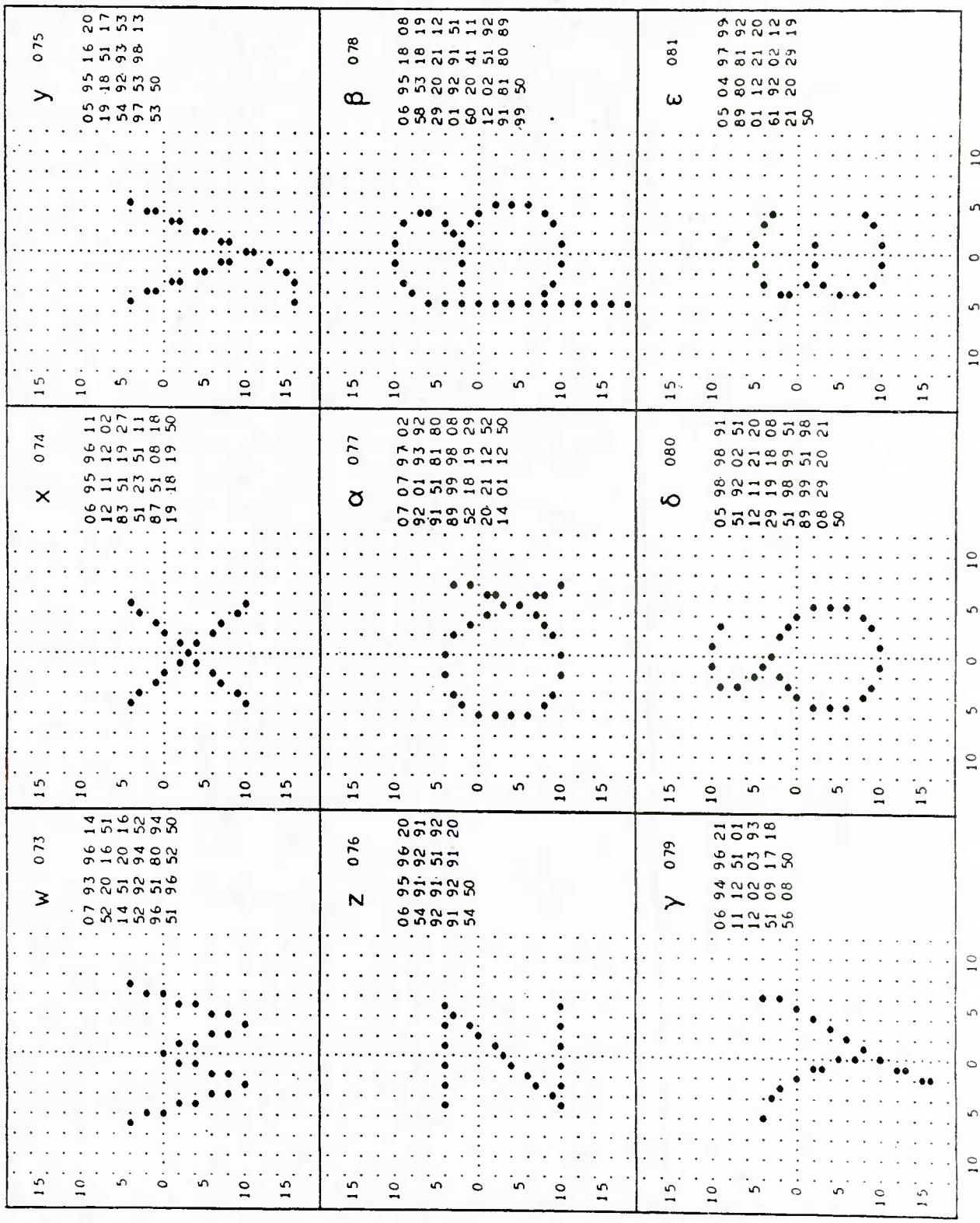


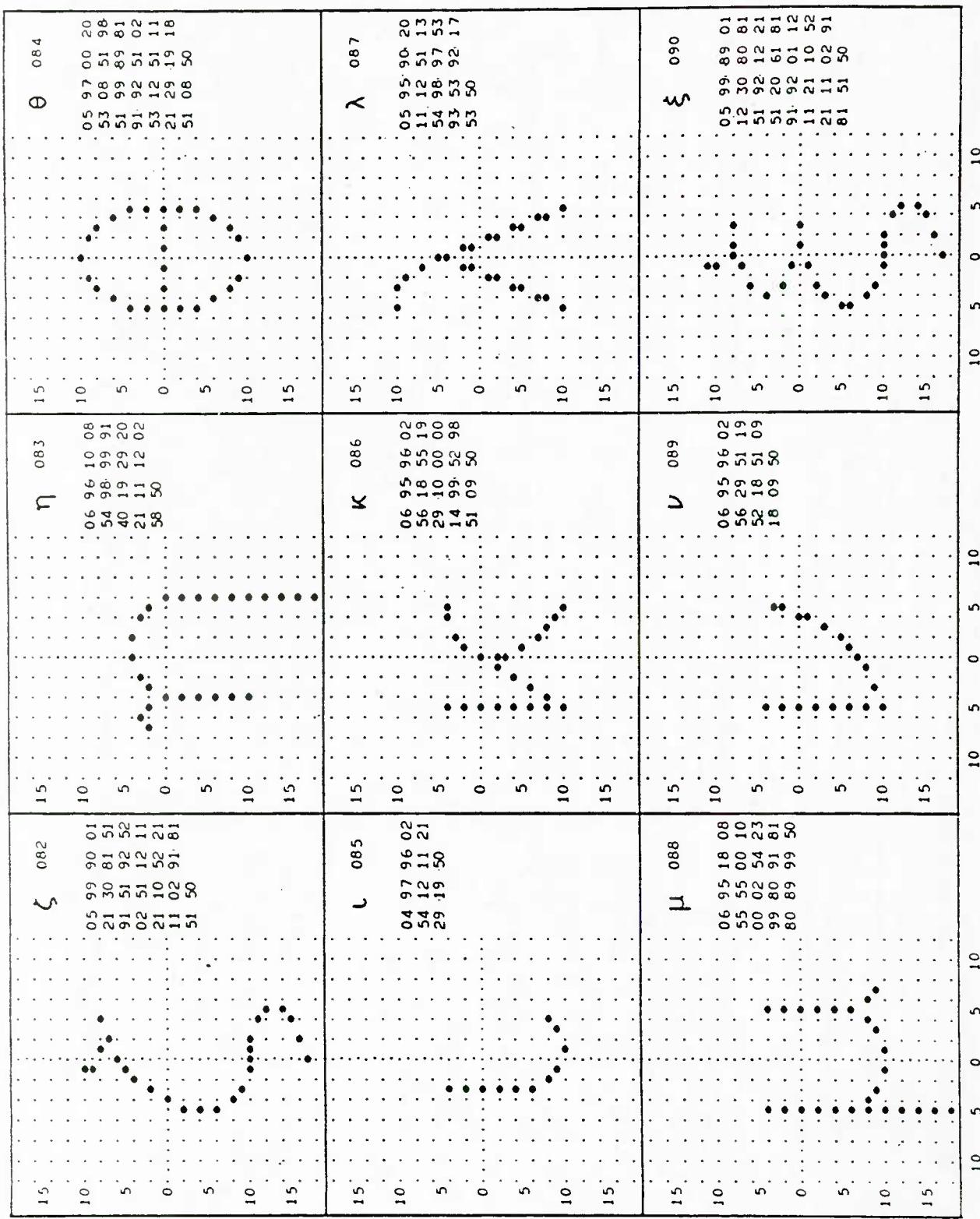


10 5 0 5 10 10 5 0 5 10 10 5 0 5 10

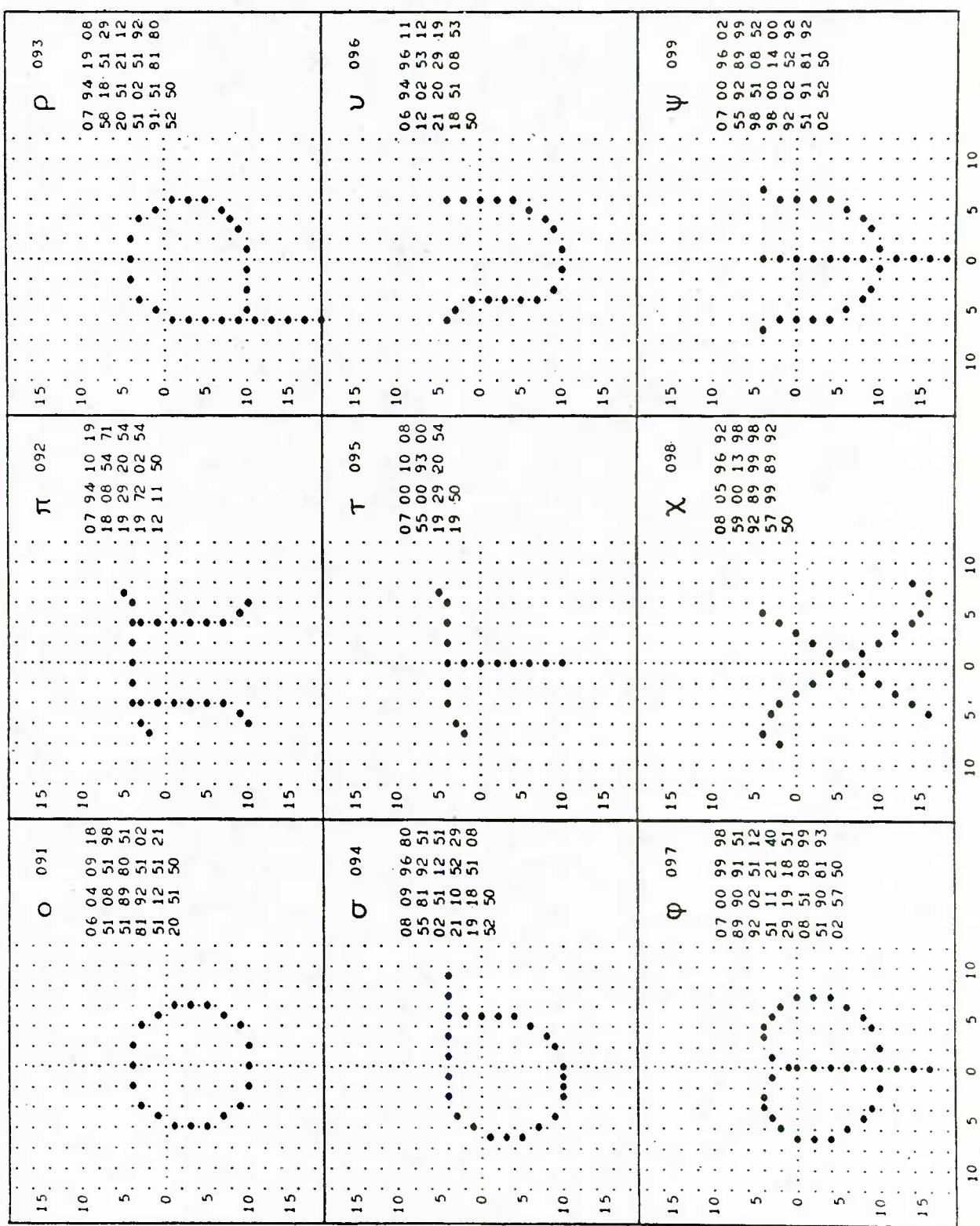


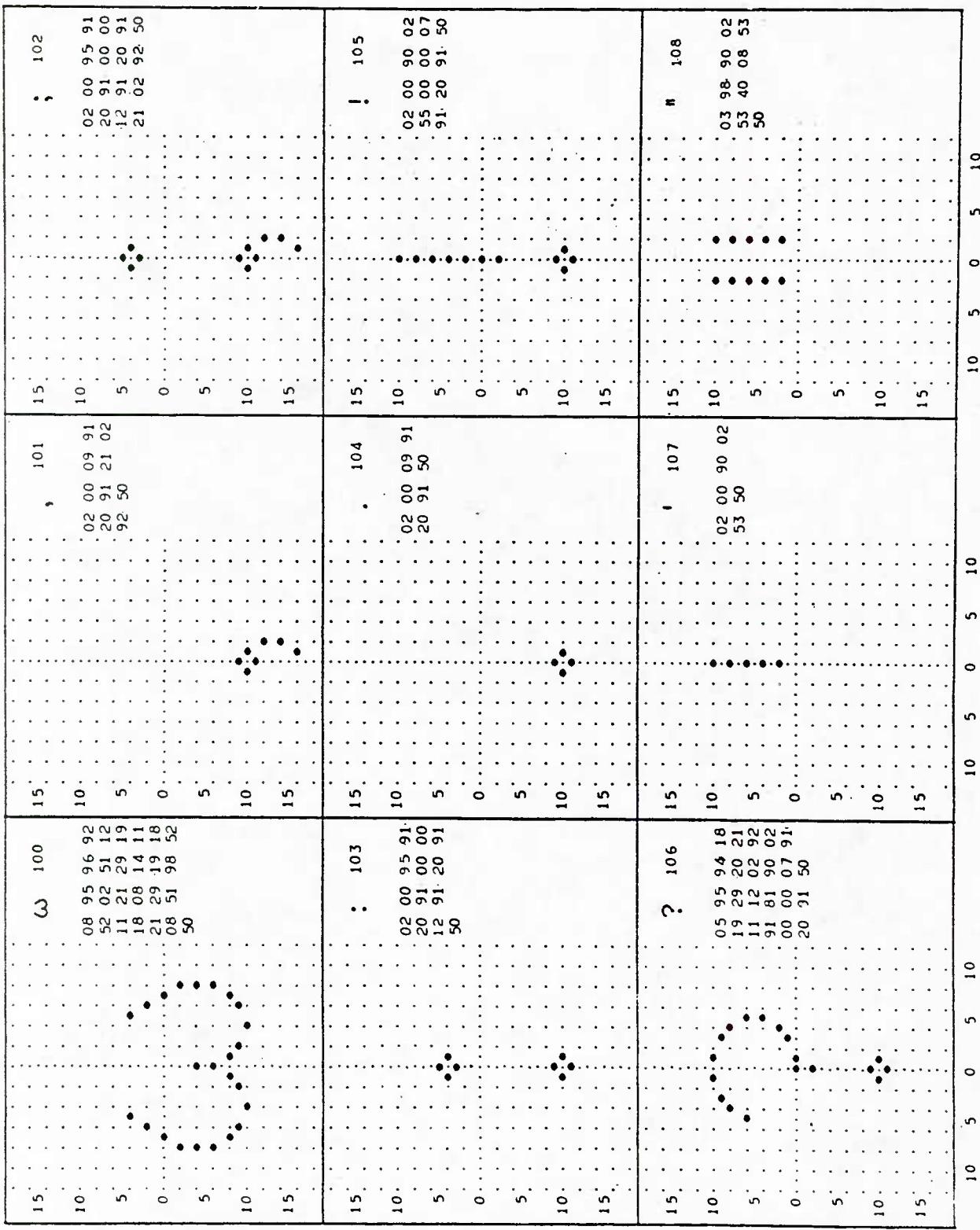


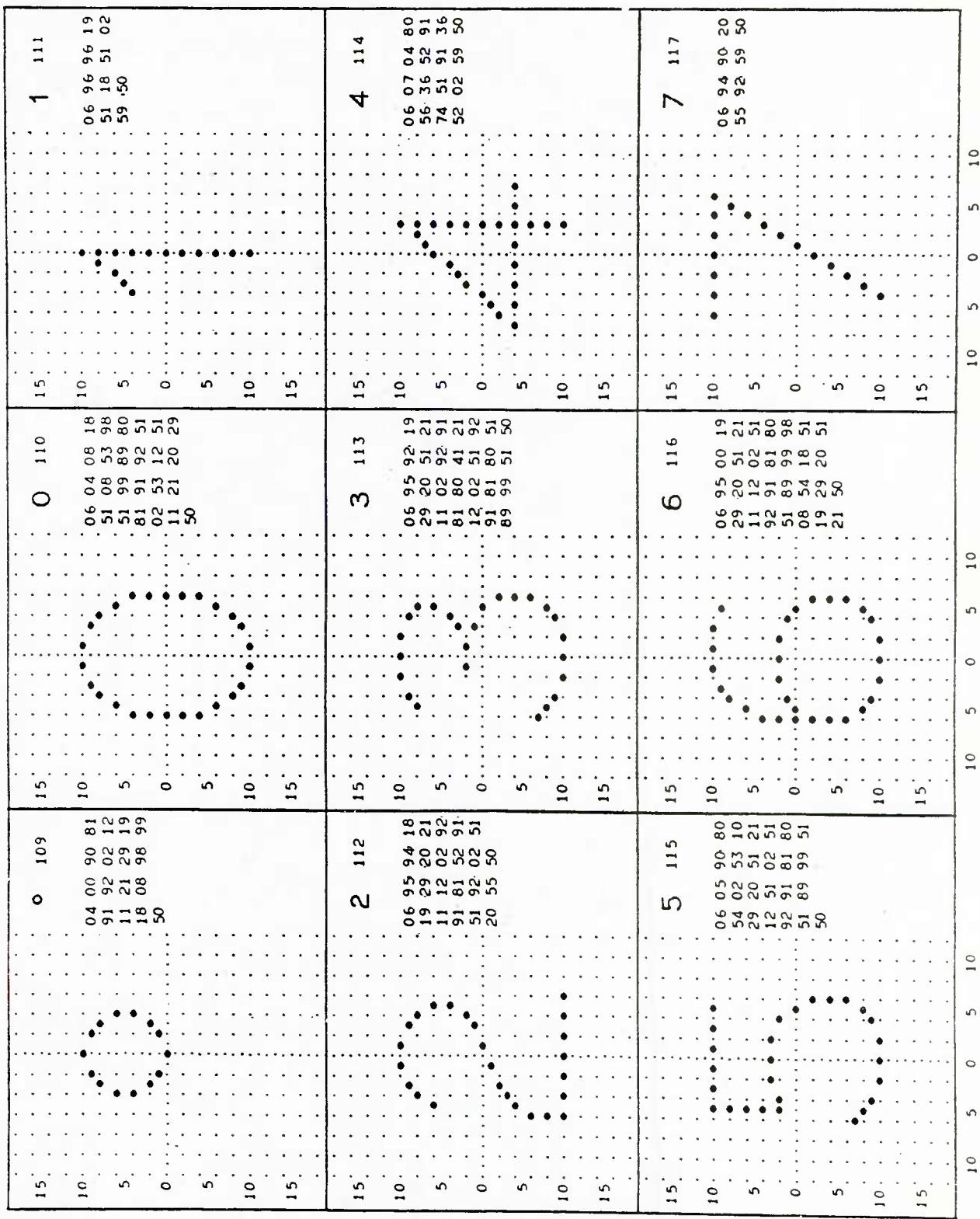


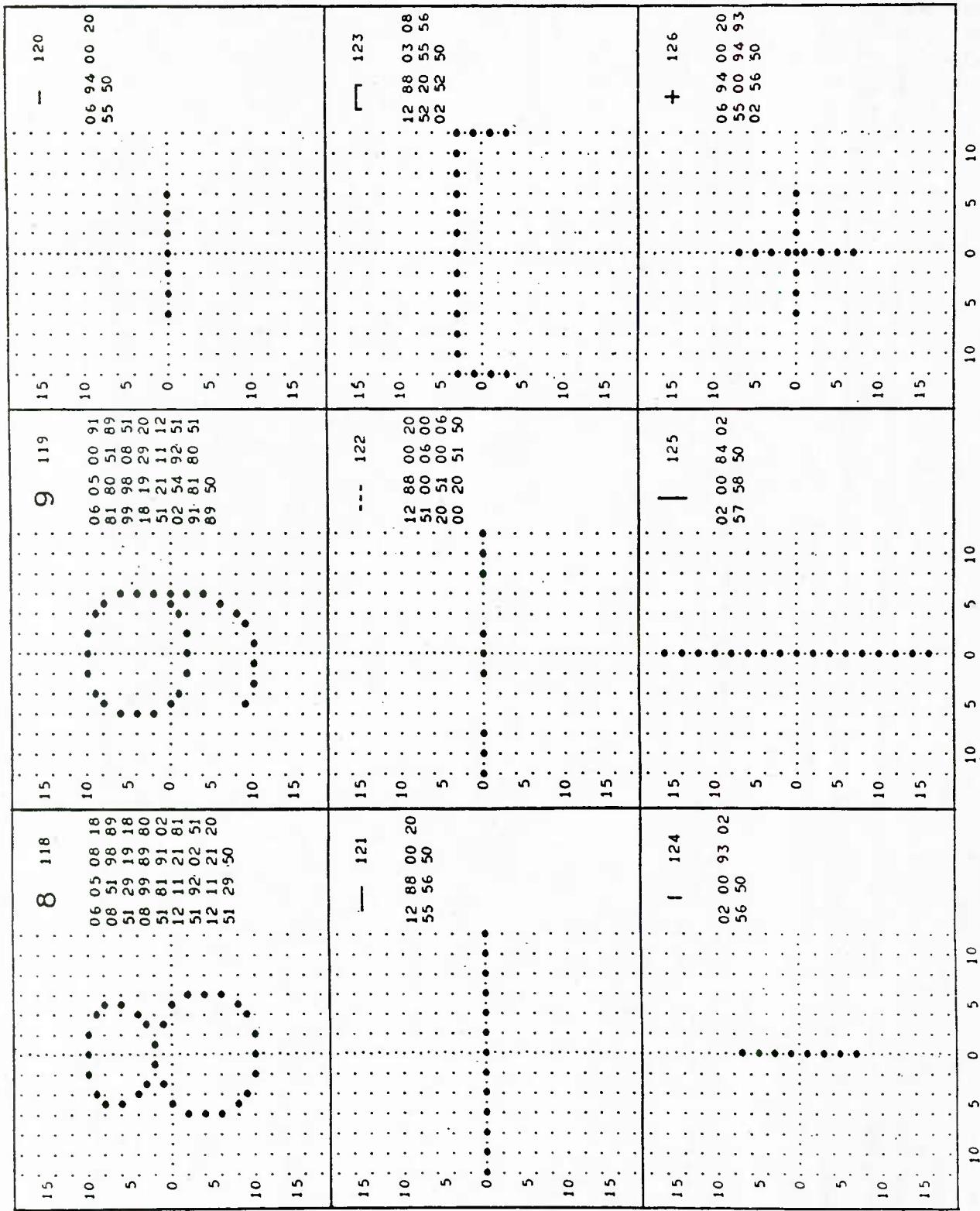


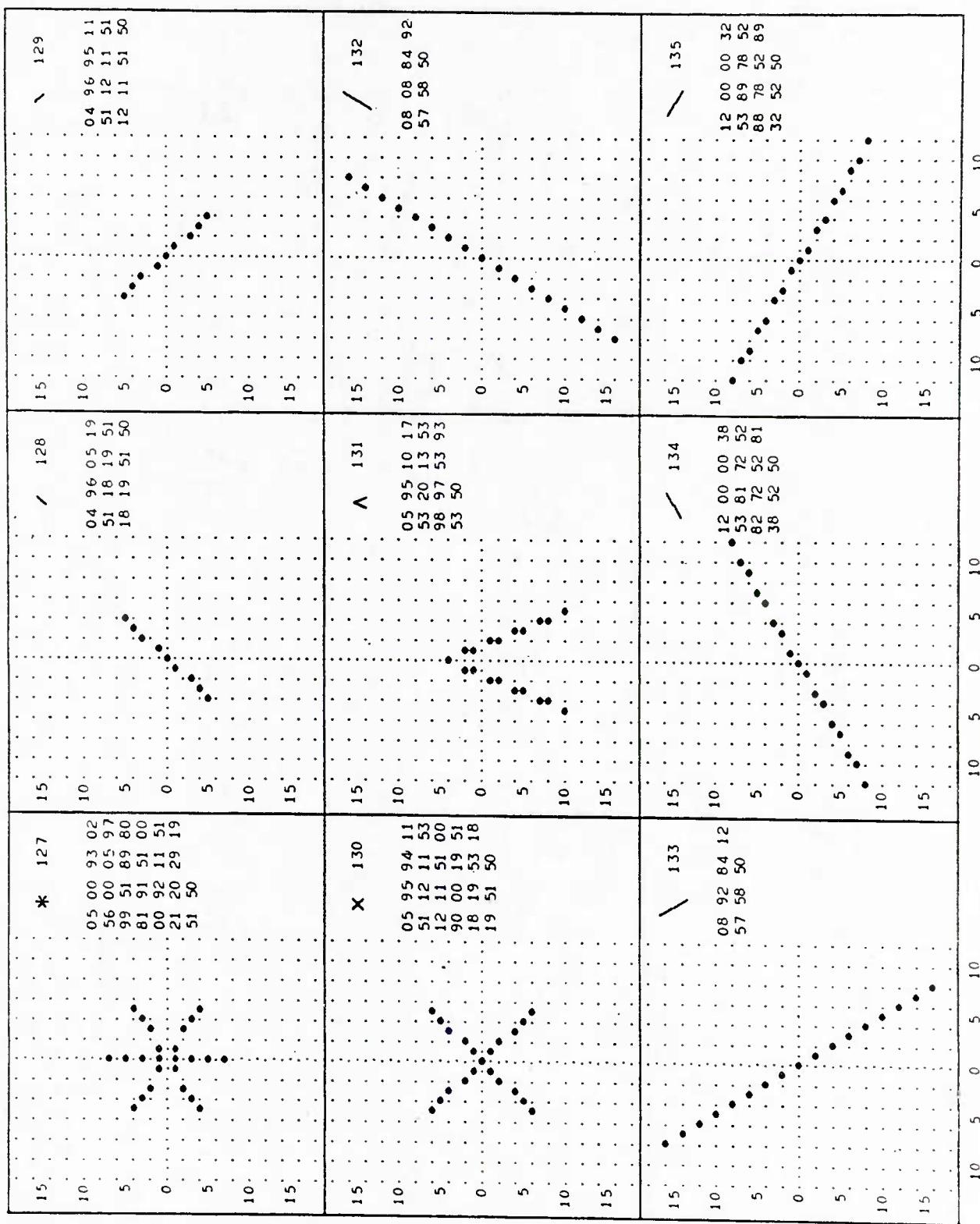
10 5 0 5 10 10 5 0 5 10 10 5 0 5 10

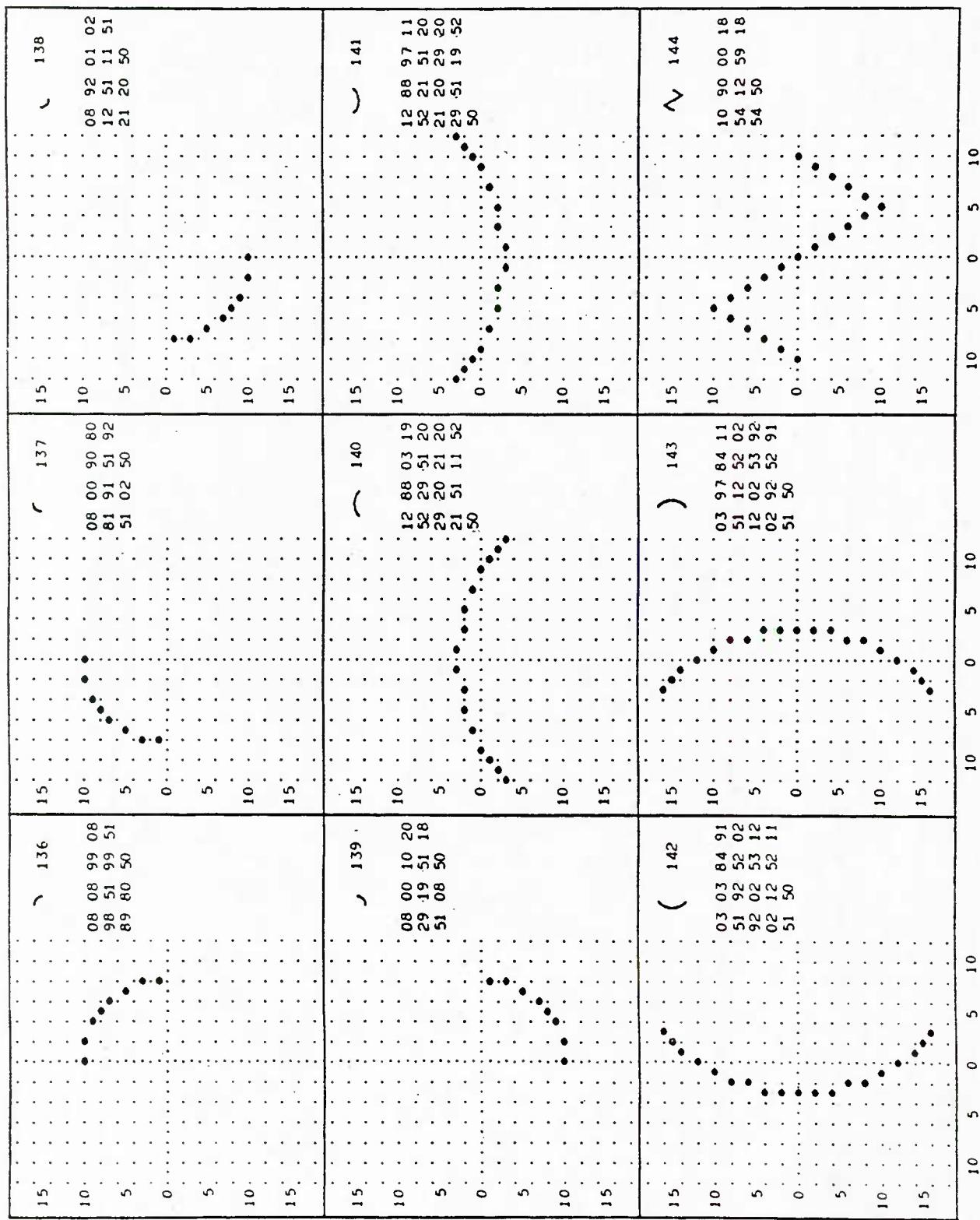


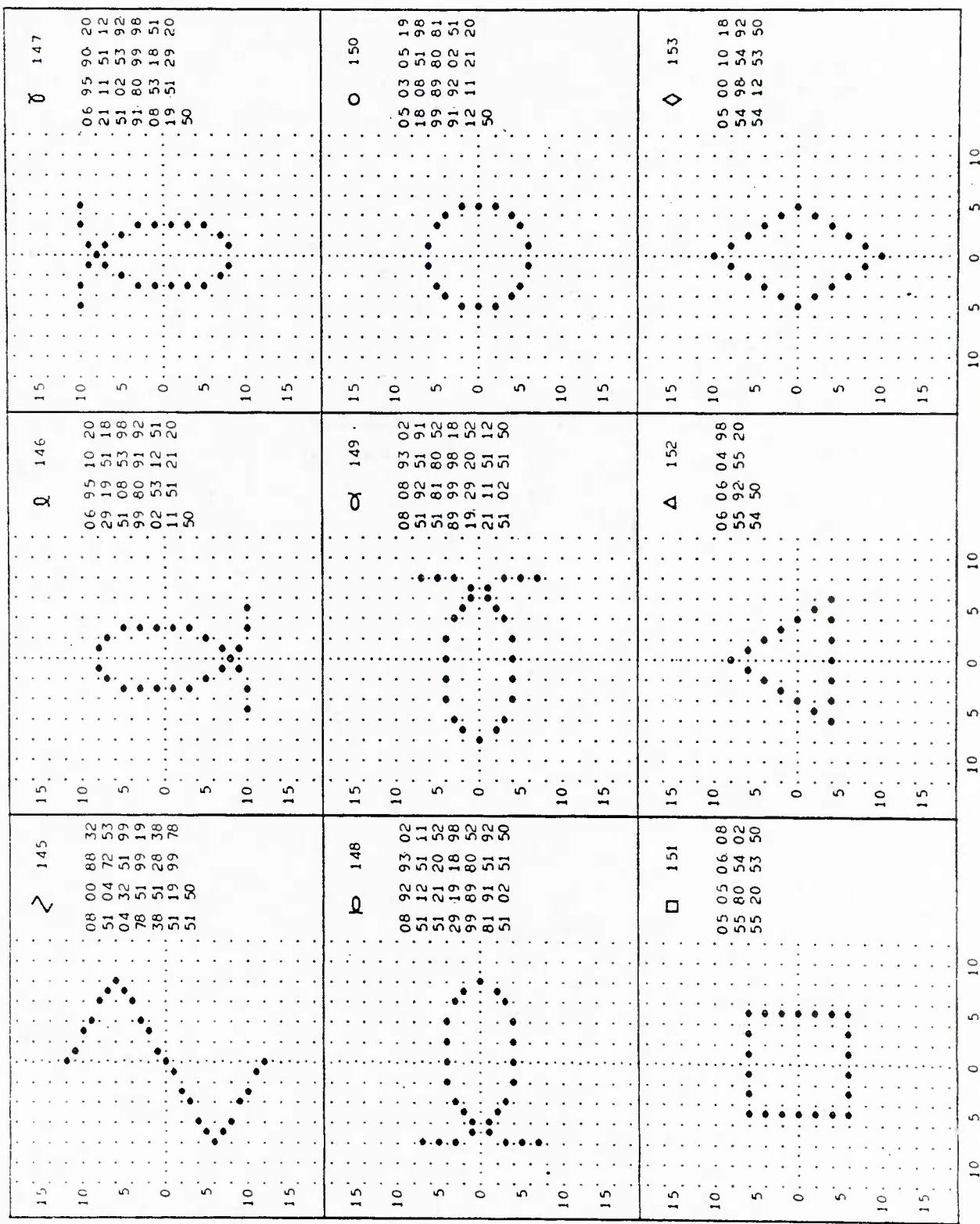




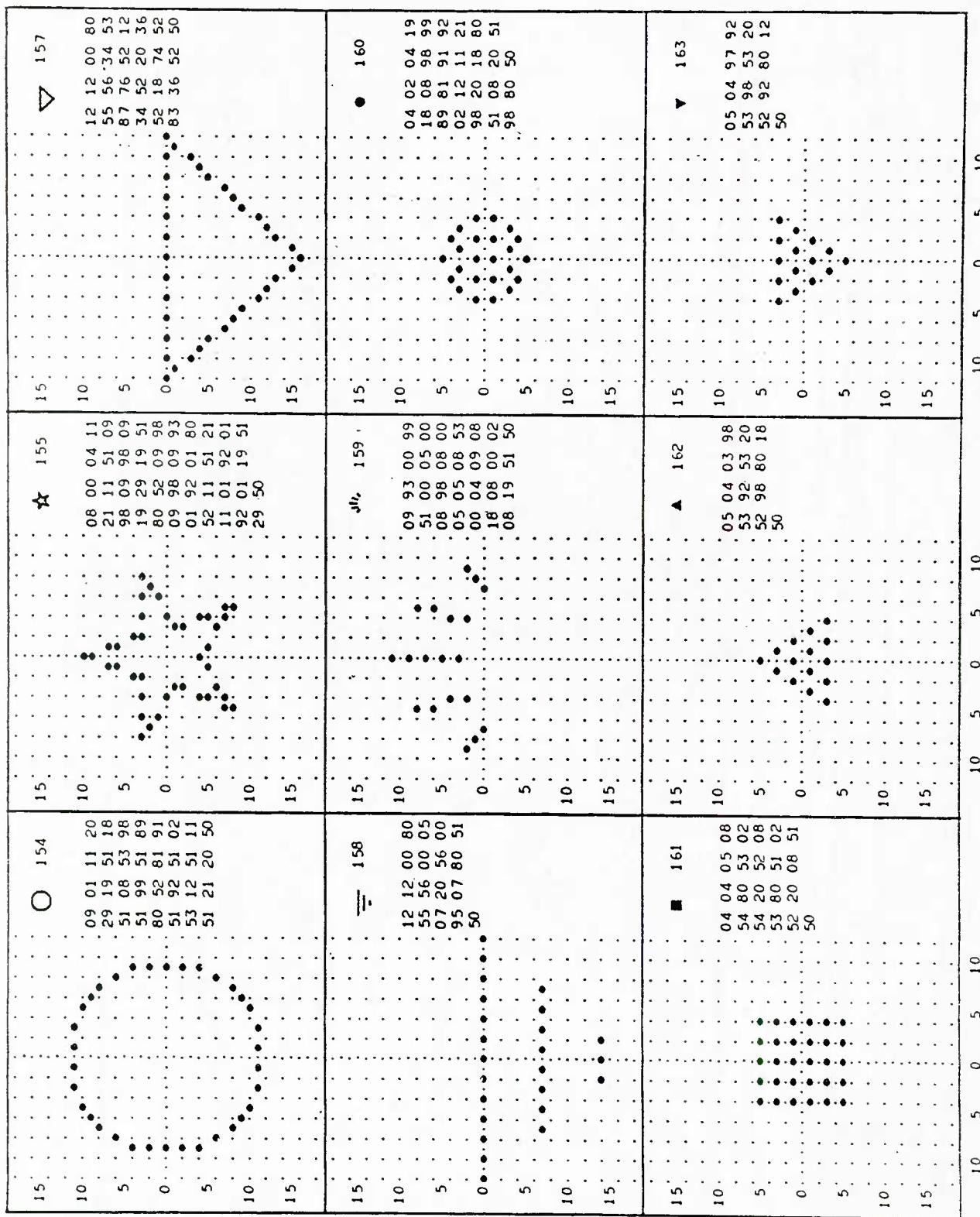


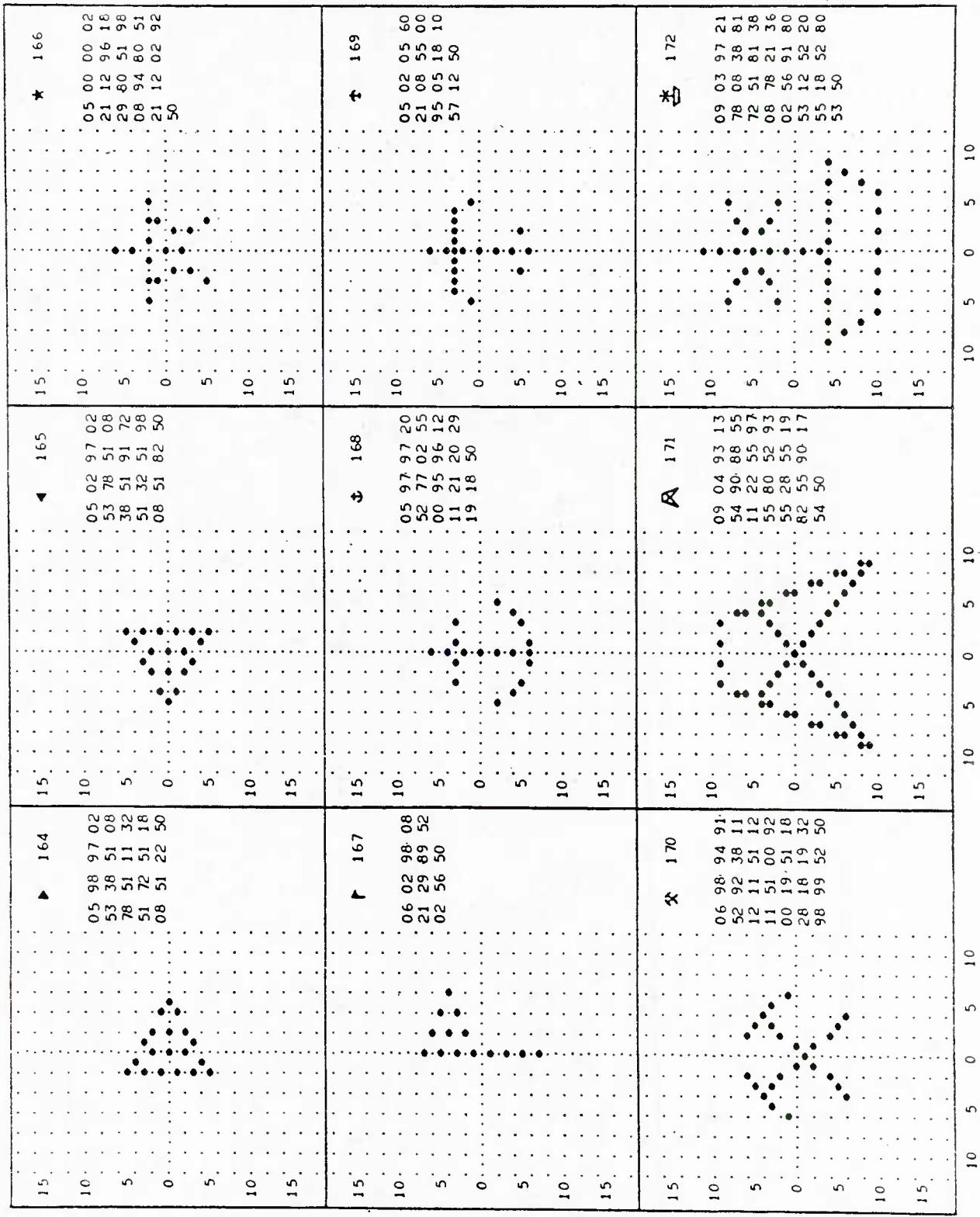




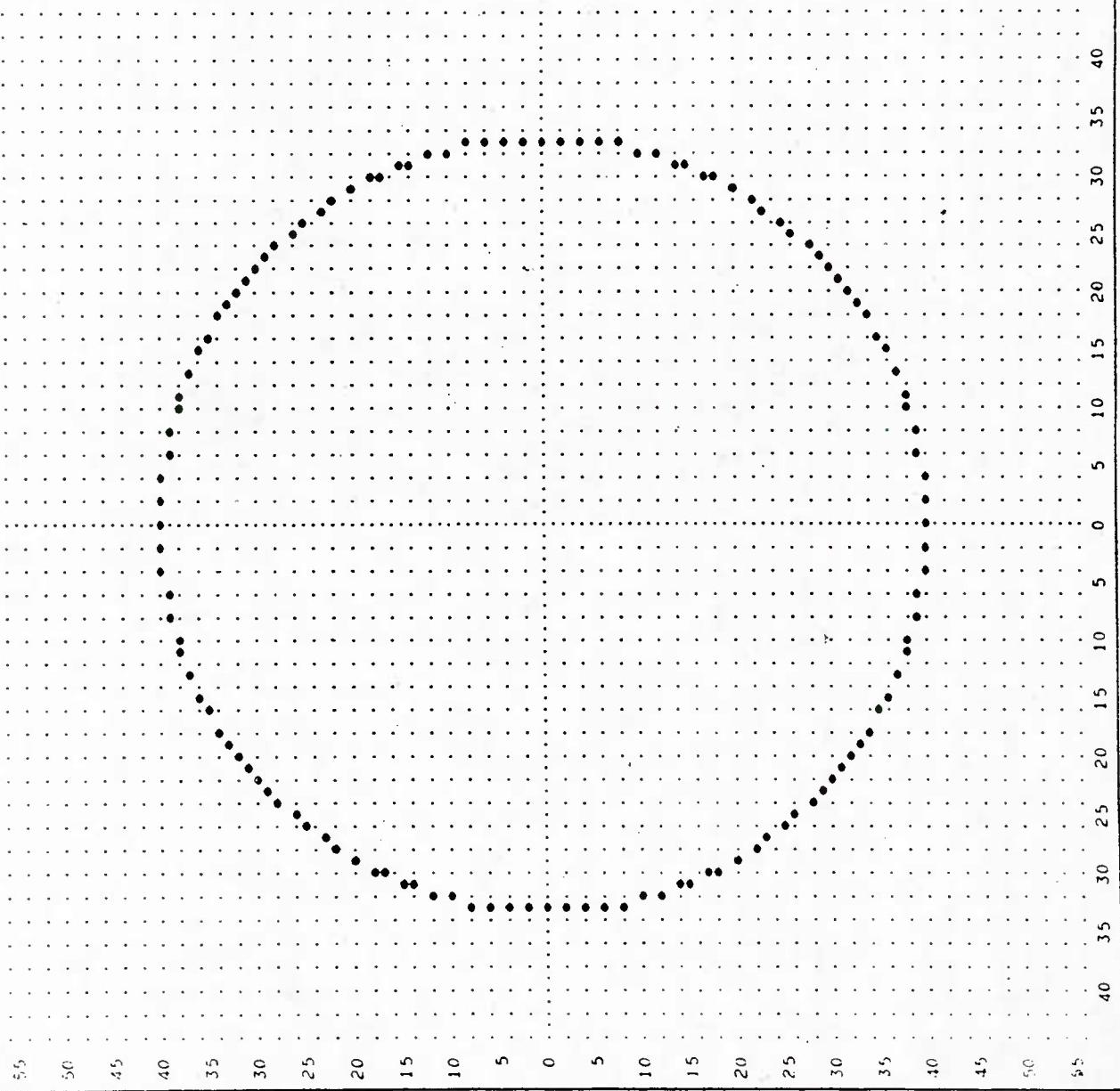


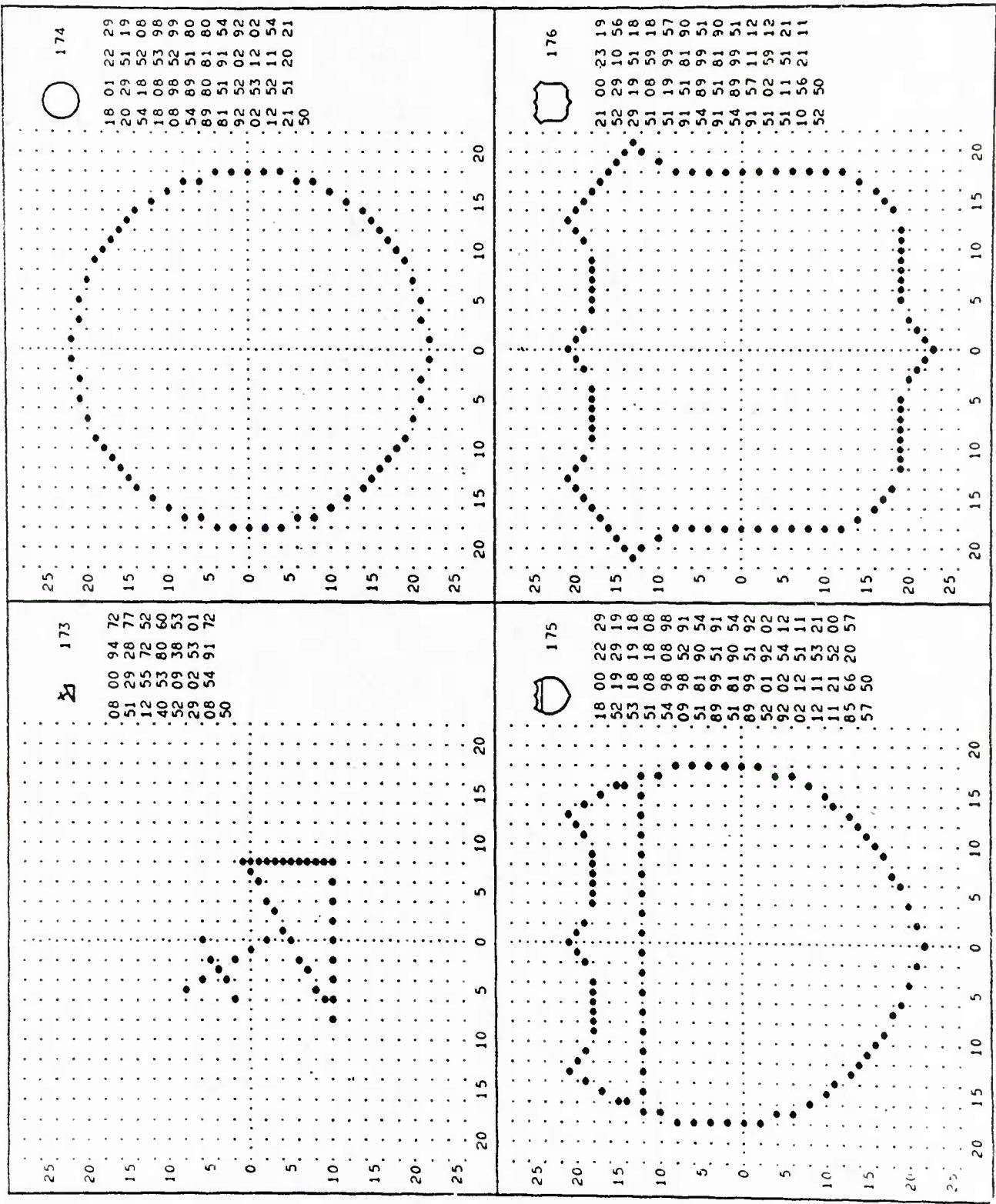
10 5 0 5 10 10 5 0 5 10 10 5 0 5 10

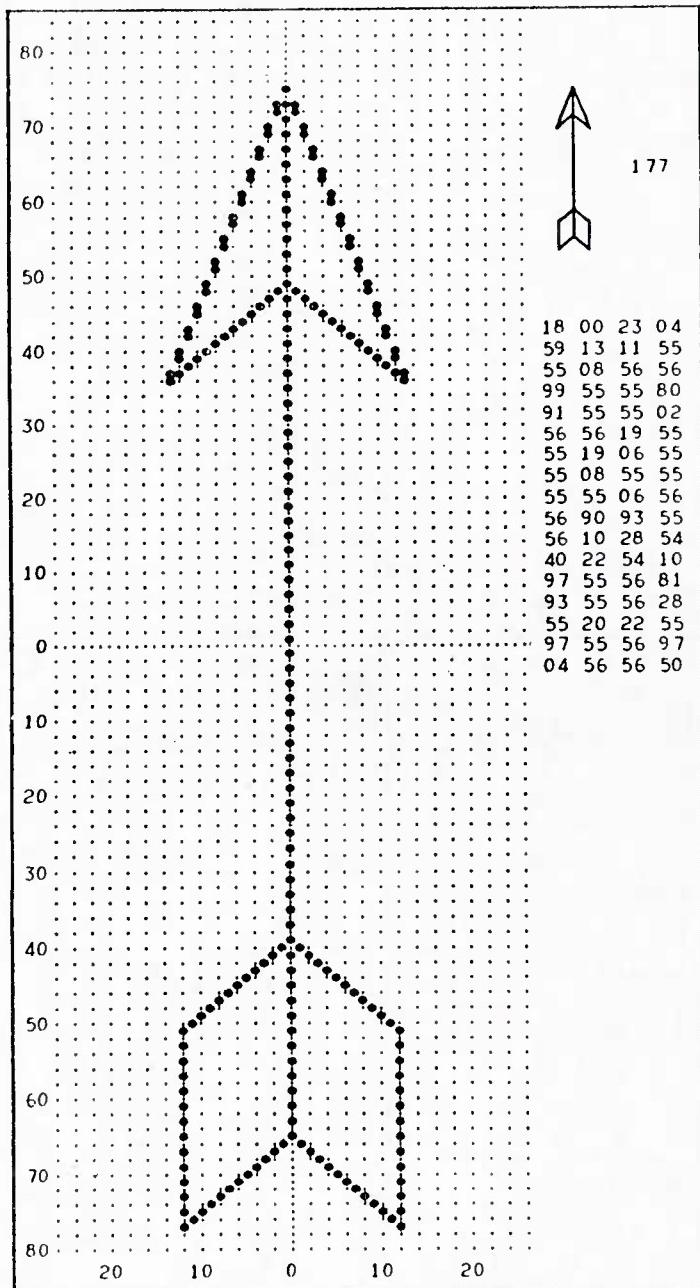




33 00 40 20 51 29 20 29
10 29 51 19 29 19 55 18
19 18 19 18 51 09 18 09
18 08 18 08 57 98 08 98
09 98 09 98 51 99 98 99
98 99 55 89 99 89 51 90
89 80 89 80 53 81 80 81
90 81 51 91 81 91 55 92
91 92 91 92 51 01 92 01
92 02 92 02 57 12 02 12
01 12 01 12 51 11 12 11
12 11 55 21 11 21 51 10
21 20 21 20 50

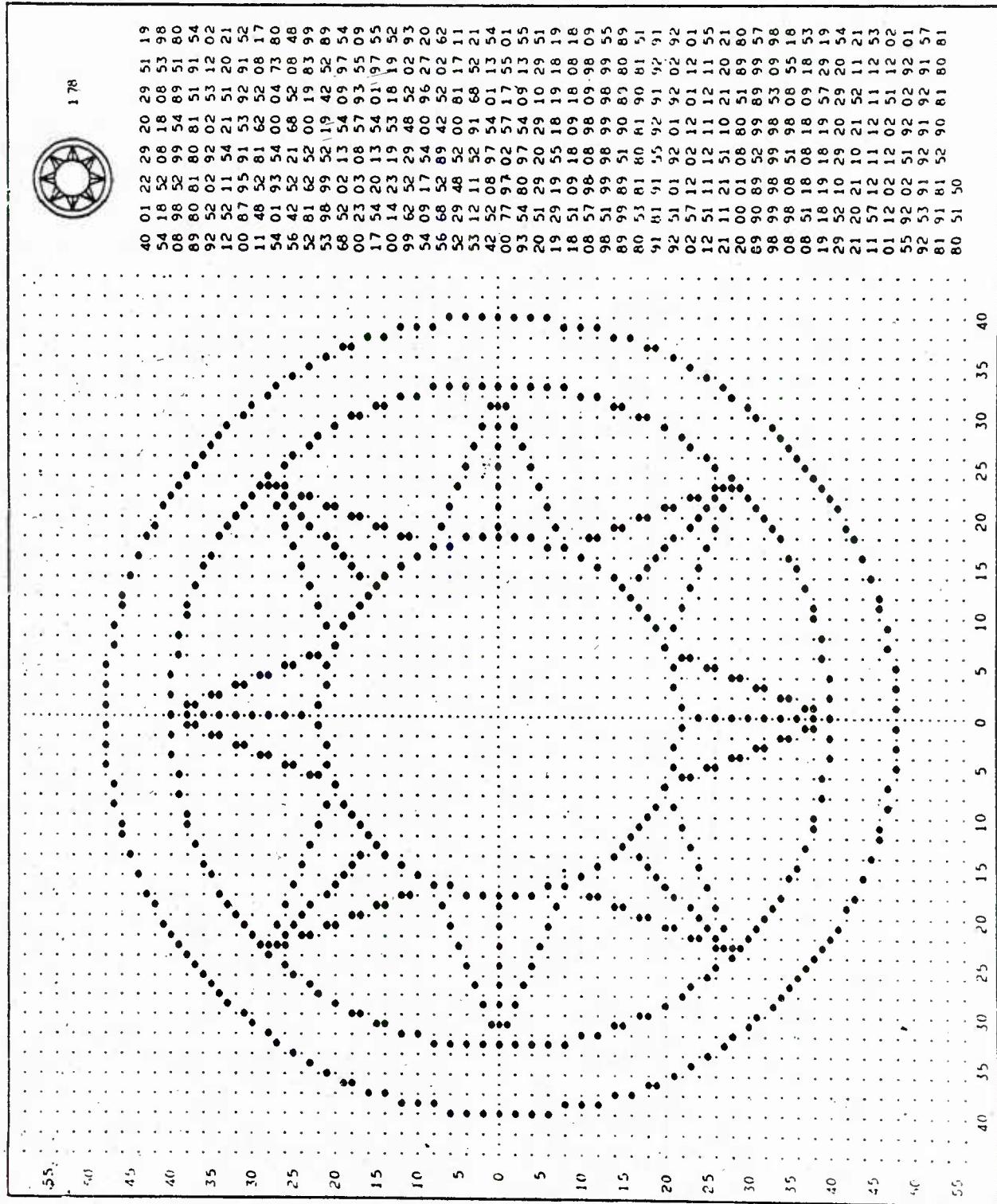








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APPENDIX B

DIGITALIZATION WITH VECTORS

DECK 2524

The border of each panel indicates the scale in raster units with every 10th raster unit accentuated. The number in each panel is the number of the character. The dots on each side of the character indicate the width of the character block.

STRETCH SUBROUTINE TO READ CHARACTER DIGITALIZATION

SUBROUTINE RDCHDT (NU, AI, AD)

NU = SYMBOLIC UNIT NUMBER (FORTRAN INTEGER)

AI = INDEX ARRAY (SYMBOLIC ADDRESS)

AD = DATUM ARRAY (SYMBOLIC ADDRESS)

STRETCH SUBROUTINE TO EXTRACT CHARACTER DIGITALIZATION

SUBROUTINE XTCHDT (NC, AI, AD, AC)

NC = CHARACTER NUMBER (FORTRAN INTEGER)

AI = INDEX ARRAY (SYMBOLIC ADDRESS)

AD = DATUM ARRAY (SYMBOLIC ADDRESS)

AC = CHARACTER ARRAY (SYMBOLIC ADDRESS)

PART I

SIMPLEX REPERTORY

A. FORTRAN

B. Cartographic

0001	0002	0003	0004	0005	0006	0007
A	B	C	D	E	F	G
0008	0009	0010	0011	0012	0013	0014
H	I	J	K	L	M	N
0015	0016	0017	0018	0019	0020	0021
O	P	Q	R	S	T	U
0022	0023	0024	0025	0026	0027	0028
V	W	X	Y	Z	A	B
0029	0030	0031	0032	0033	0034	0035
Γ	Δ	Ε	Ζ	Η	Ω	Ι
0036	0037	0038	0039	0040	0041	0042
Κ	Λ	Μ	Ν	Ξ	Ο	Π

0043	0044	0045	0046	0047	0048	0049
P	Σ	T	Υ	Φ	X	Ψ
0050	0198	0199	0200	0201	0202	0203
Ω	.	.	0	1	2	3
0204	0205	0206	0207	0208	0209	0210
4	5	6	7	8	9	.
0211	0212	0213	0214	0215	0216	0217
,	.	,	,	?	!	!!
0218	0219	0220	0221	0222	0223	0224
o	\$	/	()		-
0225	0226	0227	0228	0229		
+	=	x	*	□		

0501

0502

0503

0504

0505

A B C D E

0506

0507

0508

0509

0510

F G H I J

0511

0512

0513

0514

0515

K L M N O

0516

0517

0518

0519

0520

P Q R S T





0561	0562	0563	0564	0565
K	L	M	N	O
0566	0567	0568	0569	0570
P	Q	R	S	T
0571	0572	0573	0574	0575
U	V	W	X	Y
0576	0583			
Z	▼			

a 0601	b 0602	c 0603	d 0604	e 0605
f 0606	g 0607	h 0608	i 0609	j 0610
k 0611	l 0612	m 0613	n 0614	o 0615
p 0616	q 0617	r 0618	s 0619	t 0620

0621	0622	0623	0624	0625
u	v	w	x	y
0626	0627	0628	0629	0630
z	α	β	γ	δ
0631	0632	0633	0634	0635
ε	ζ	η	ϑ	ι
0636	0637	0638	0639	0640
κ	λ	μ	ν	ξ

0641	0642	0643	0644	0645
O	π	p	σ	T
0646	0647	0648	0649	0650
v	φ	x	ψ	w
0651	0652	0653	0654	0655
a	b	c	d	e
0656	0657	0658	0659	0660
f	g	h	i	j

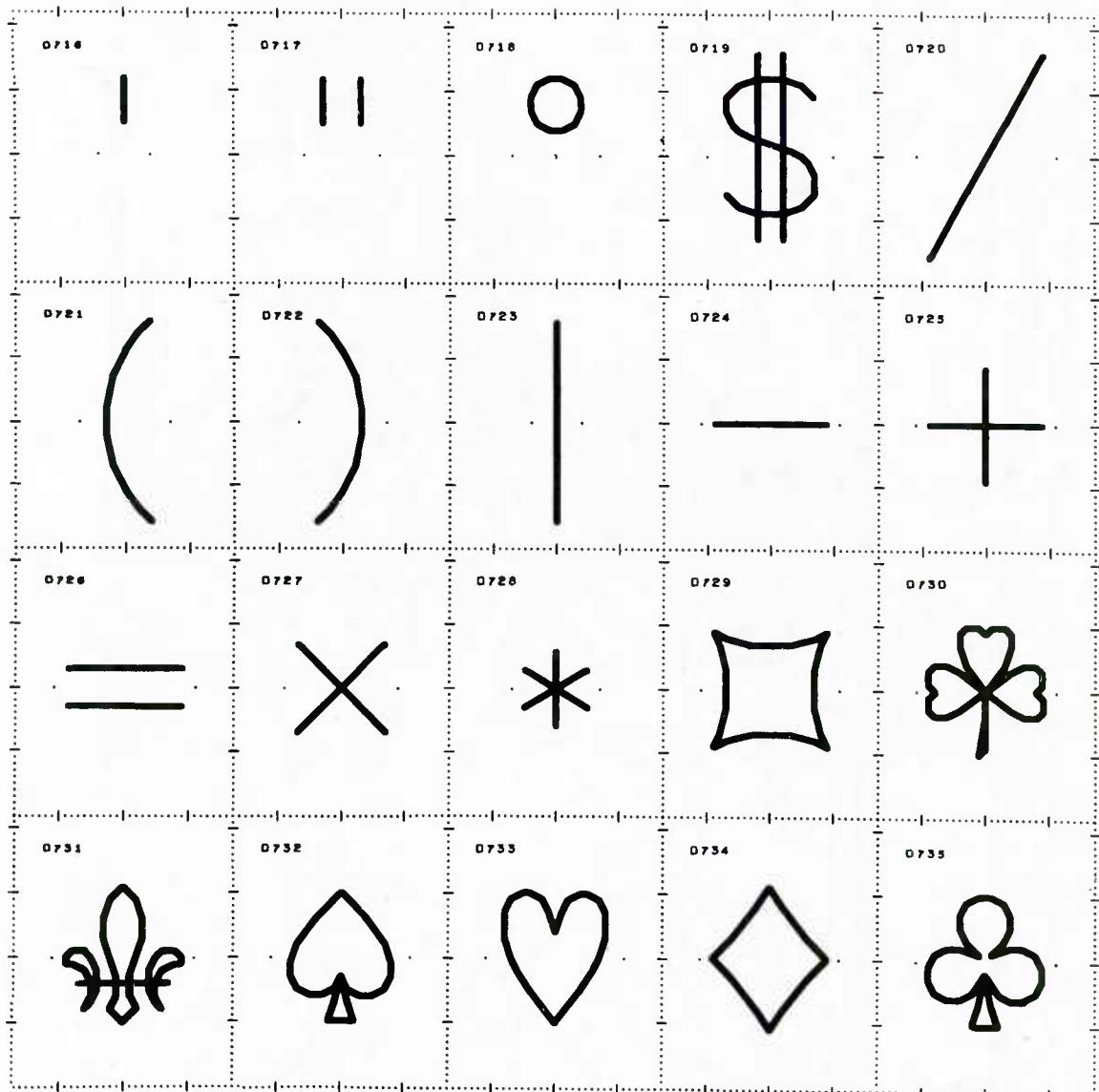
k l m n o

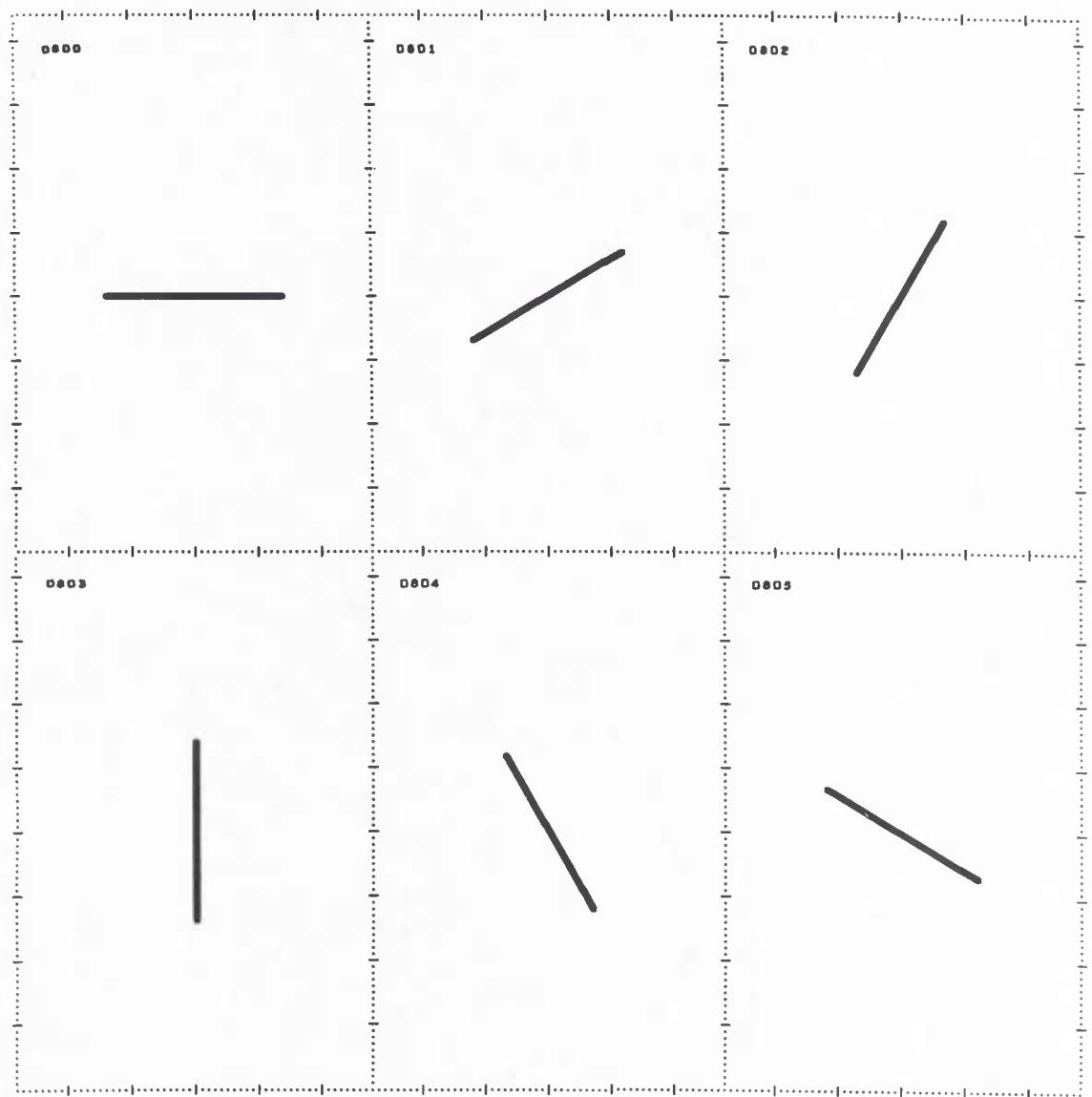
p g r s t

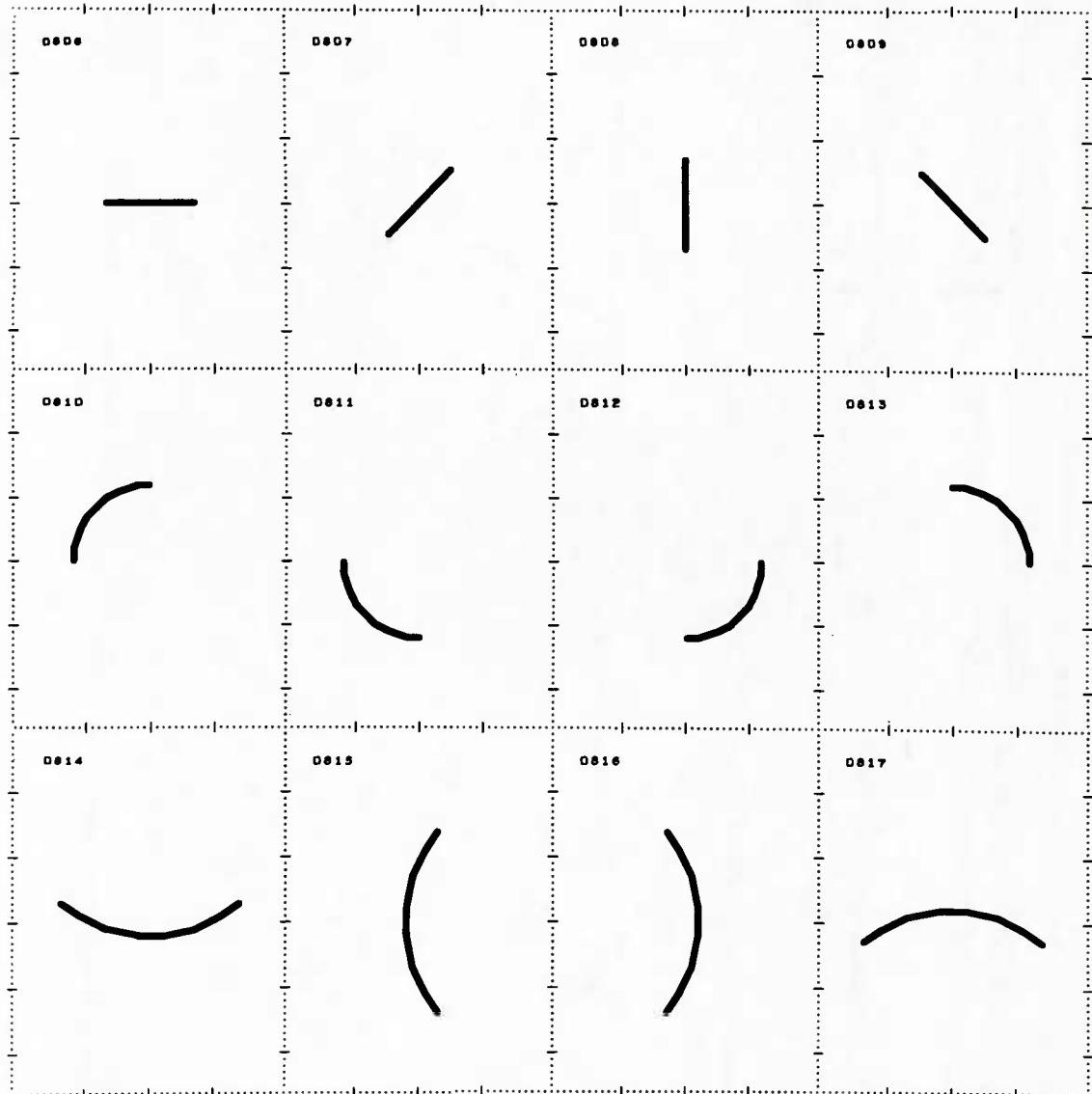
u u w x y

z ä ē ö ø

	0698	0699	0700	0701
0702	0703	0704	0705	0706
2	3	4	5	6
0707	0708	0709	0710	0711
7	8	9	,	,
0712	0713	0714	0715	?
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,	,			







0820



0822



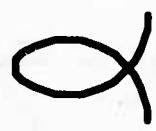
0824



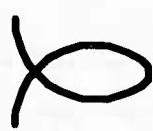
0821

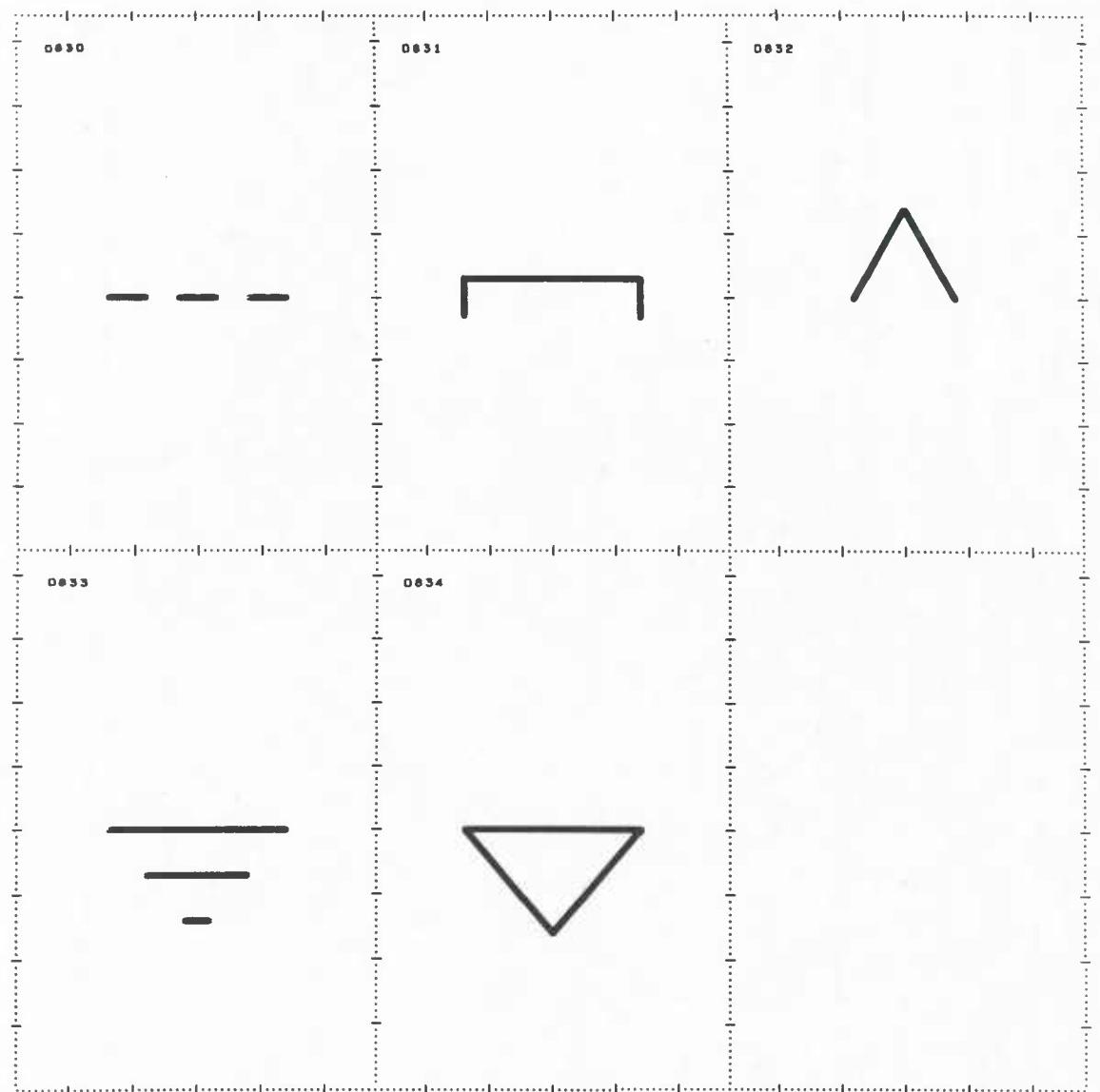


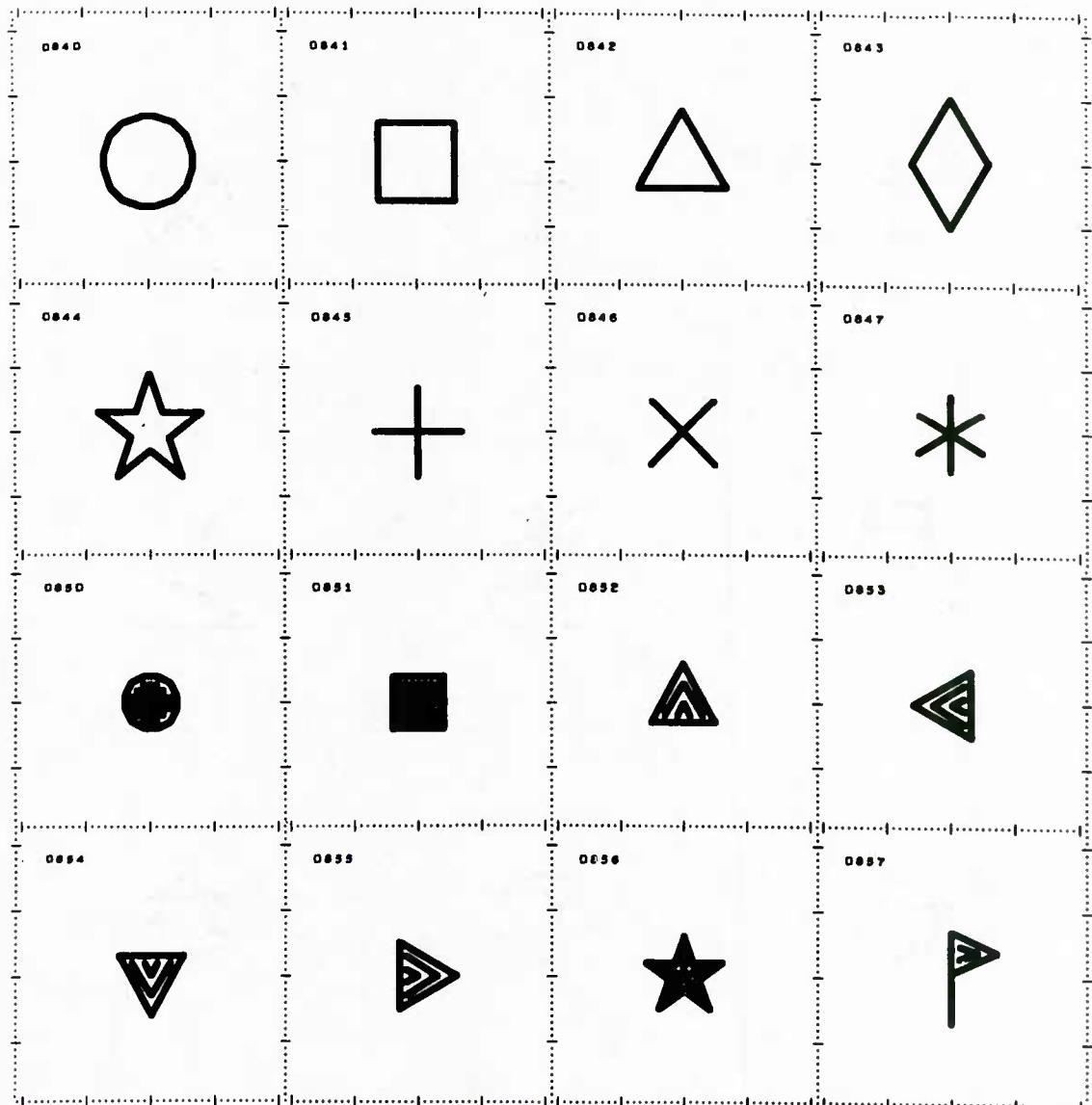
0823

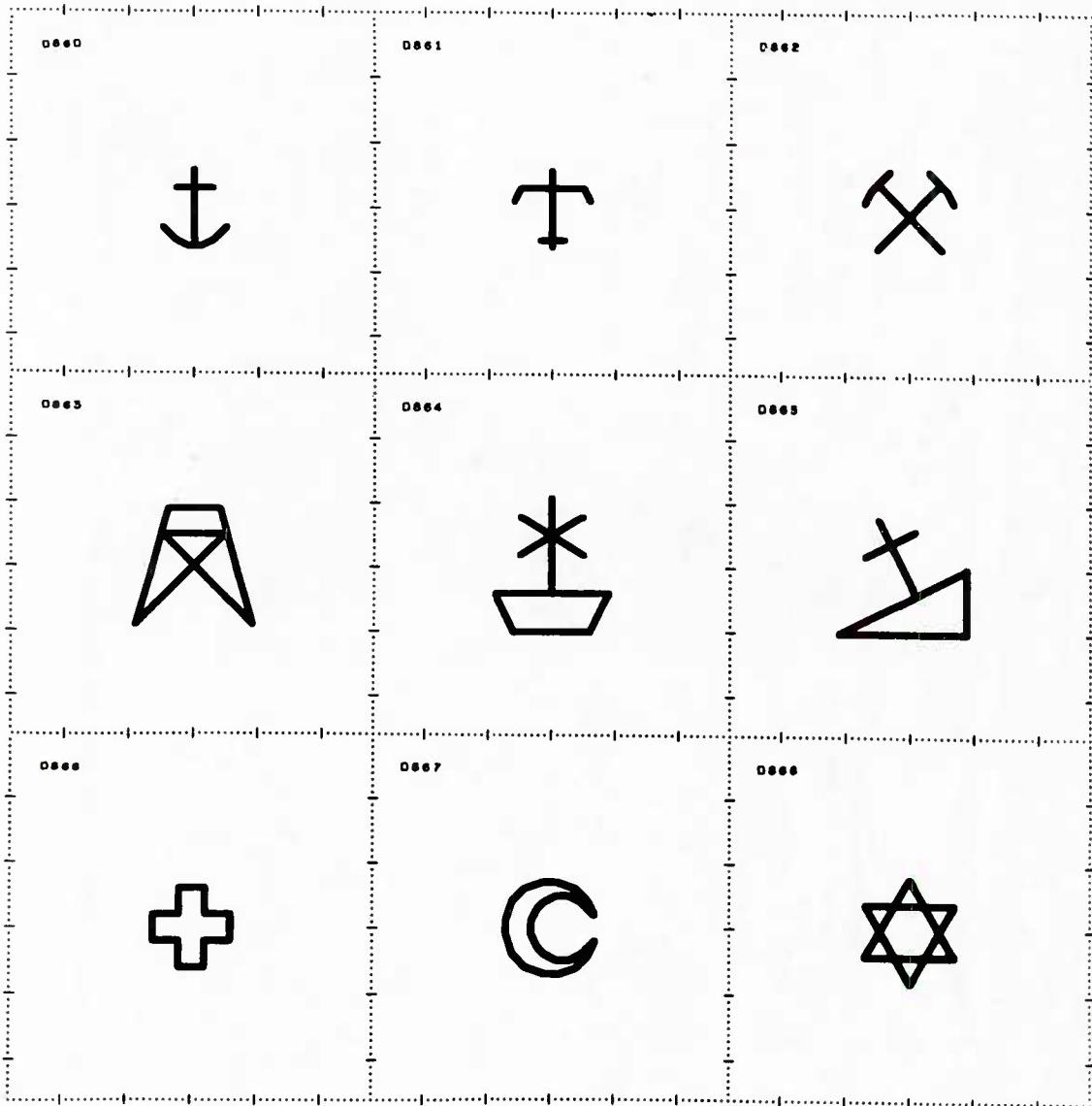


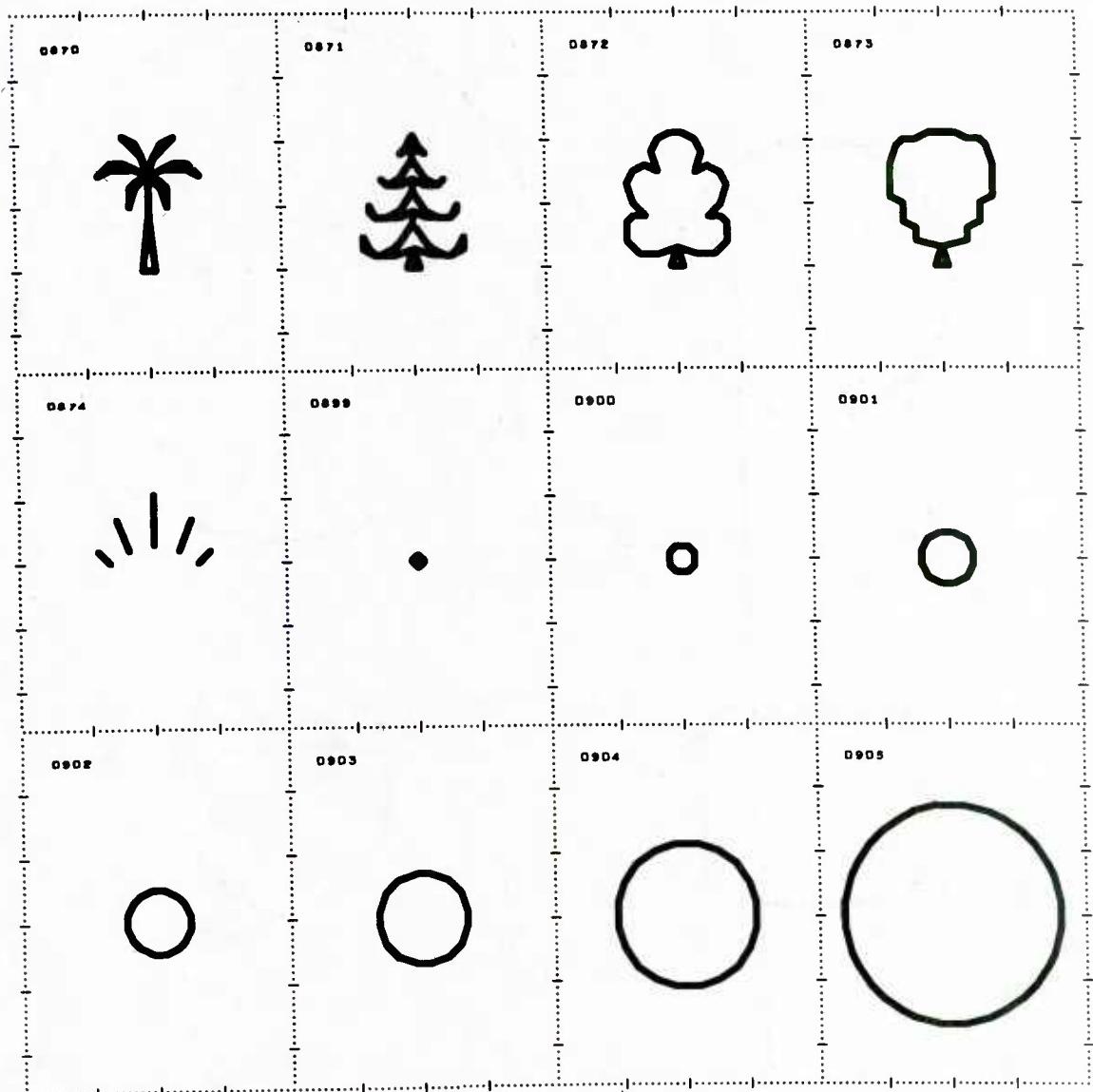
0825

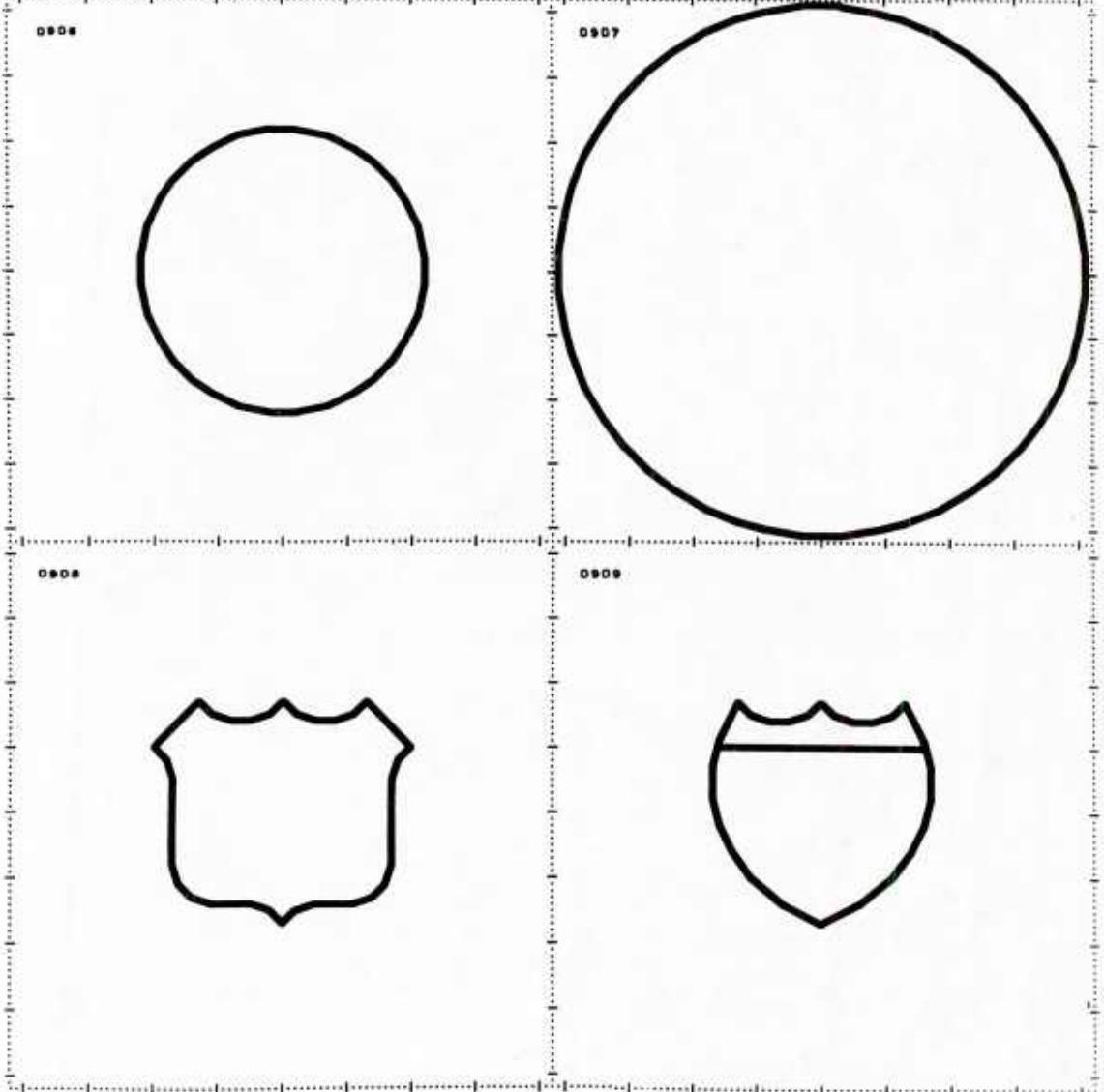












PART II

DUPLEX REPERTORY

A. Indexical

B. Principal

1001	1002	1003	1004	1005
A	B	C	D	E
1006	1007	1008	1009	1010
F	G	H	I	J
1011	1012	1013	1014	1015
K	L	M	N	O
1016	1017	1018	1019	1020
P	Q	R	S	T

1021	1022	1023	1024	1025
U	V	W	X	Y
1026	1027	1028	1029	1030
Z	A	B	Γ	Δ
1031	1032	1033	1034	1035
E	Z	H	Θ	I
1036	1037	1038	1039	1040
K	Λ	M	N	Ξ

1041	1042	1043	1044	1045
O	Π	P	Σ	T
1046	1047	1048	1049	1050
Υ	Φ	X	Ψ	Ω
1051	1052	1053	1054	1055
A	B	C	D	E
1056	1057	1058	1059	1060
F	G	H	I	J

1061	1062	1063	1064	1065
<i>K</i>	<i>L</i>	<i>M</i>	<i>N</i>	<i>O</i>
1066	1067	1068	1069	1070
<i>P</i>	<i>Q</i>	<i>R</i>	<i>S</i>	<i>T</i>
1071	1072	1073	1074	1075
<i>U</i>	<i>V</i>	<i>W</i>	<i>X</i>	<i>Y</i>
1076				
<i>Z</i>				

1101	1102	1103	1104	1105
a	b	c	d	e
1106	1107	1108	1109	1110
f	g	h	i	j
1111	1112	1113	1114	1115
k	l	m	n	o
1116	1117	1118	1119	1120
p	q	r	s	t

1121	1122	1123	1124	1125	
u	v	w	x	y	
1126	1127	1128	1129	1130	
z	α	β	γ	δ	
1131	1132	1133	1134	1135	
ε	ξ	η	ϑ	ι	
1136	1137	1138	1139	1140	
κ	λ	μ	ν	ξ	

1141	1142	1143	1144	1145
\circ	π	ρ	σ	τ
1146	1147	1148	1149	1150
v	φ	χ	ψ	ω
1151	1152	1153	1154	1155
a	b	c	d	e
1156	1157	1158	1159	1160
f	g	h	i	j

1161	1162	1163	1164	1165
<i>k</i>	<i>l</i>	<i>m</i>	<i>n</i>	<i>o</i>
1166	1167	1168	1169	1170
<i>p</i>	<i>q</i>	<i>r</i>	<i>s</i>	<i>t</i>
1171	1172	1173	1174	1175
<i>u</i>	<i>v</i>	<i>w</i>	<i>x</i>	<i>y</i>
1176				
<i>z</i>				

1177

1178

1179

1180

1181

ff**fi****fl****ffi****ffl**

1184

1185

1186

€**θ****φ**

1191

1192

1193

1194

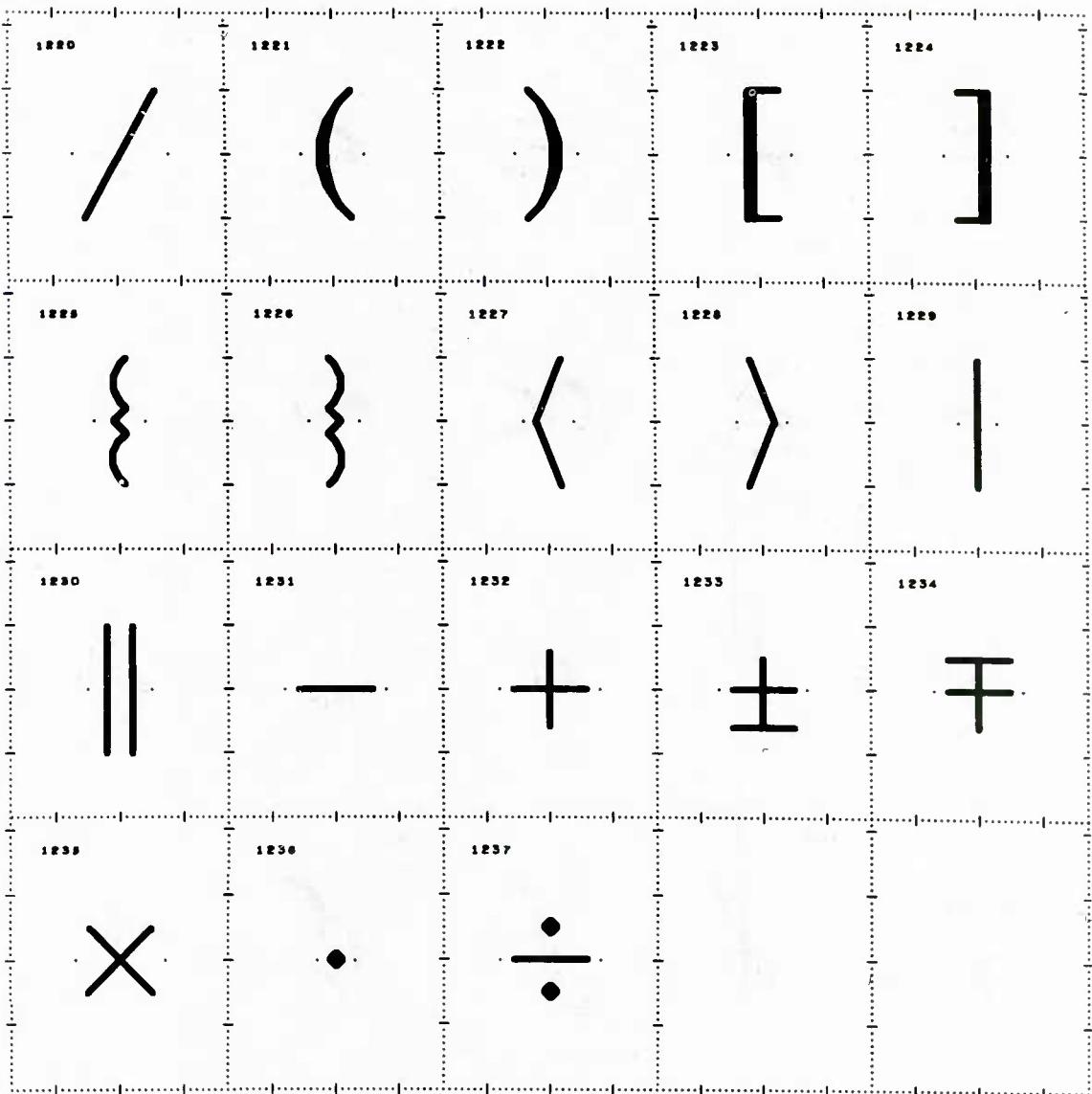
1195

ff**fi****fl****ffi****ffl**

1196

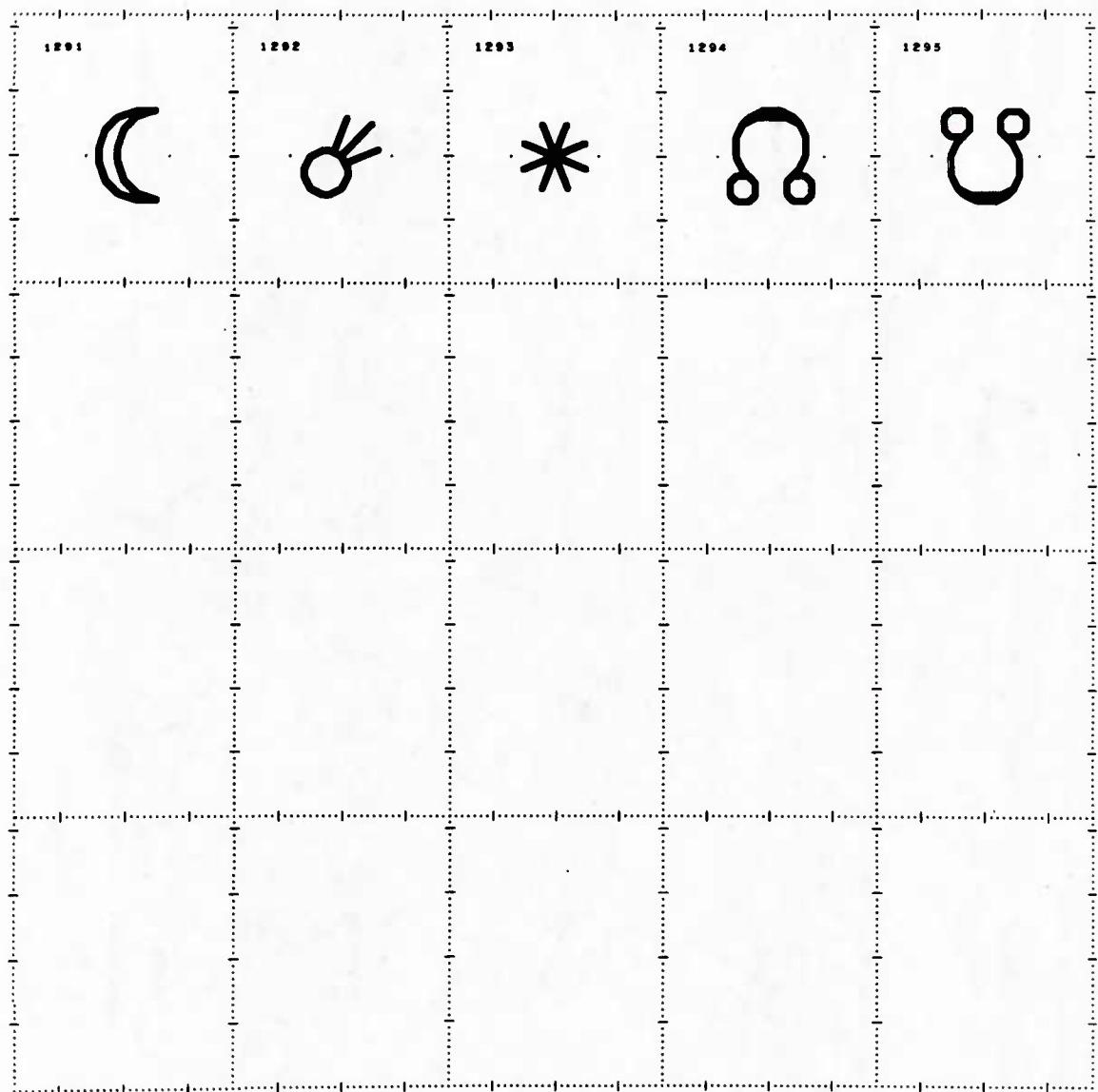
1199

1200	1201	1202	1203	1204
0	1	2	3	4
1205	1206	1207	1208	1209
5	6	7	8	9
1210	1211	1212	1213	1214
,	,	,	,	!
1215	1216	1217	1218	1219
?	!	"	o	*



1238	1239	1240	1241	1242
=	≠	≡	<	>
≤	≥	∞	?	↗
→	↑	←	↓	∂
▽	√	∫	ƒ	∞

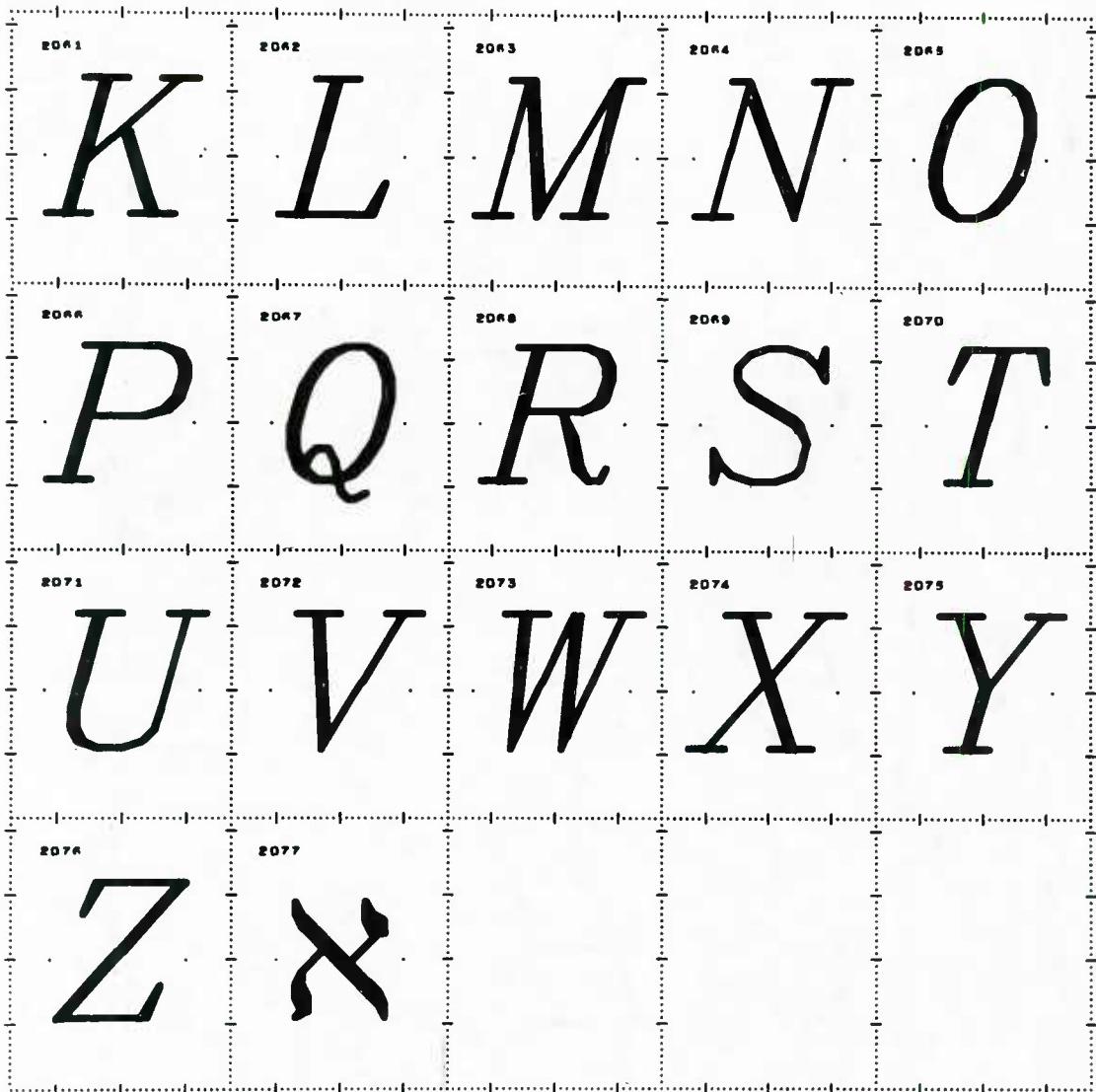
1271	1272	1273	1274	1275
%	&	@	\$	#
1276	1277	1278		
ø	☩	☩		
1281	1282	1283	1284	1285
○•	♀	♀	⊕	♂
1286	1287	1288	1289	1290
⌚	☿	♂	Ψ	ᴱ



2001	2002	2003	2004	2005
A	B	C	D	E
2006	2007	2008	2009	2010
F	G	H	I	J
2011	2012	2013	2014	2015
K	L	M	N	O
2016	2017	2018	2019	2020
P	Q	R	S	T



2041	2042	2043	2044	2045
O	Π	P	Σ	T
2046	2047	2048	2049	2050
Υ	Φ	X	Ψ	Ω
2051	2052	2053	2054	2055
A	B	C	D	E
2056	2057	2058	2059	2060
F	G	H	I	J



a b c d e

f g h i j

k l m n o

p q r s t

2101

2102

2103

2104

2105

2106

2107

2108

2109

2110

2111

2112

2113

2114

2115

2116

2117

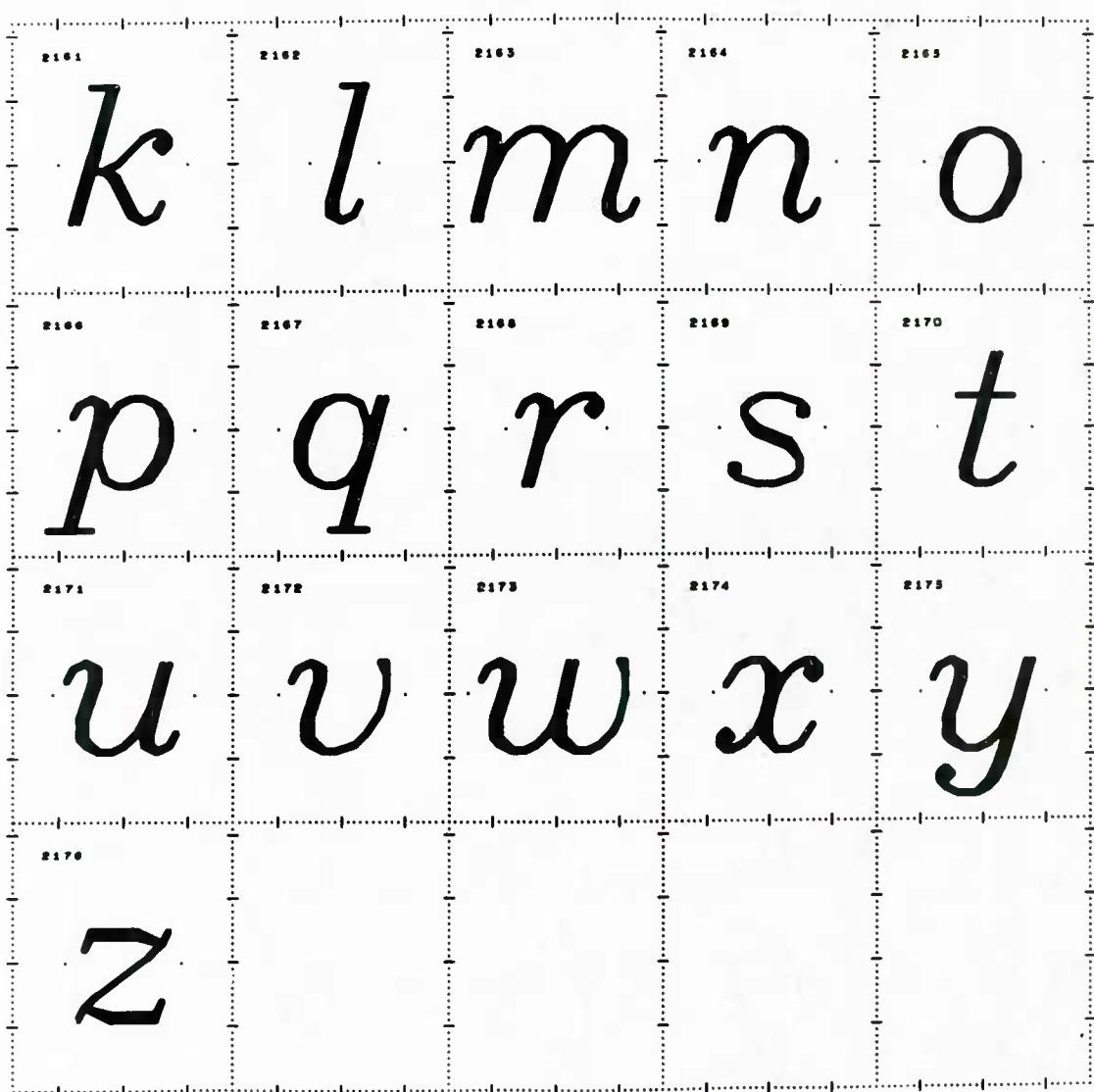
2118

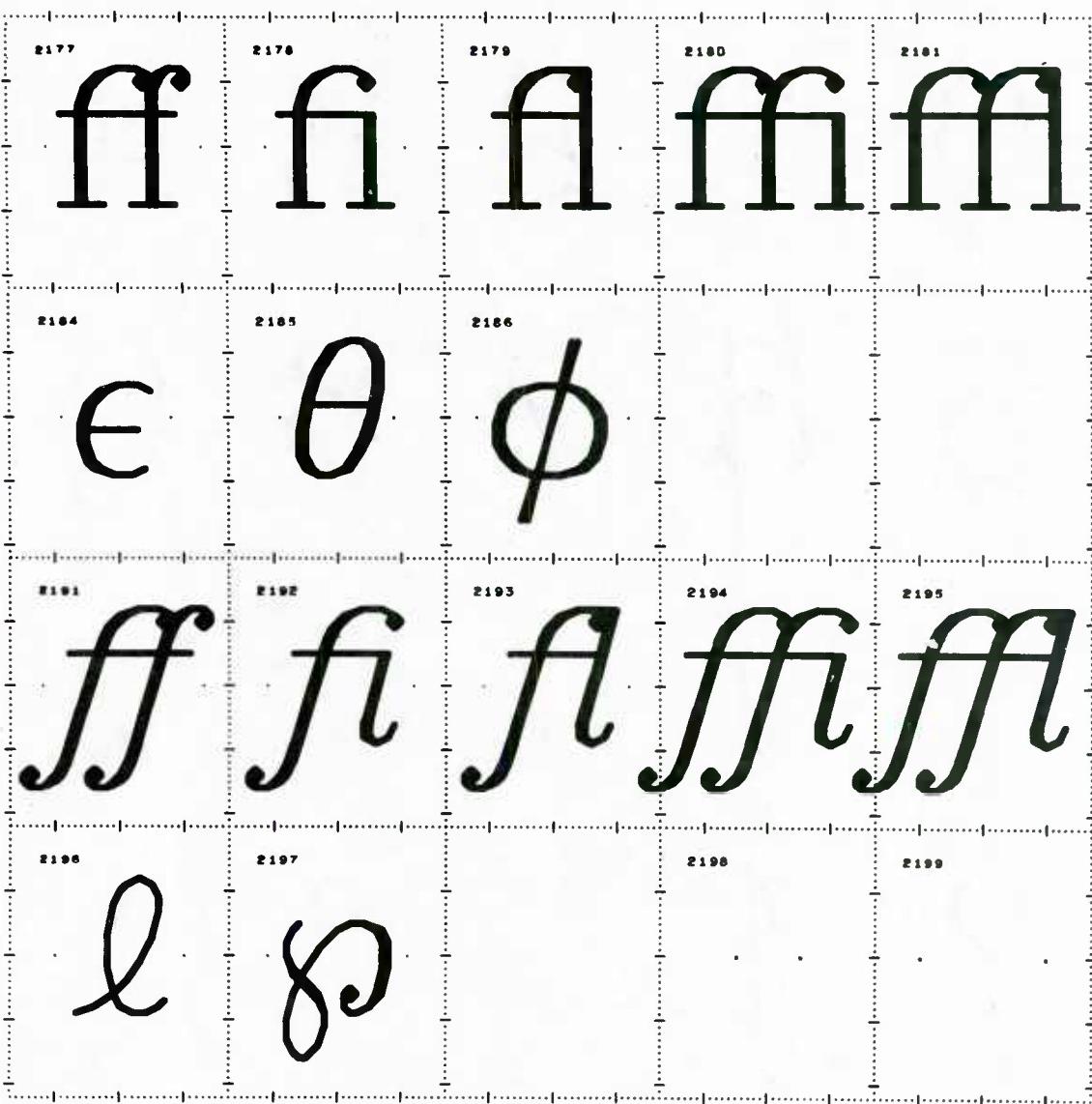
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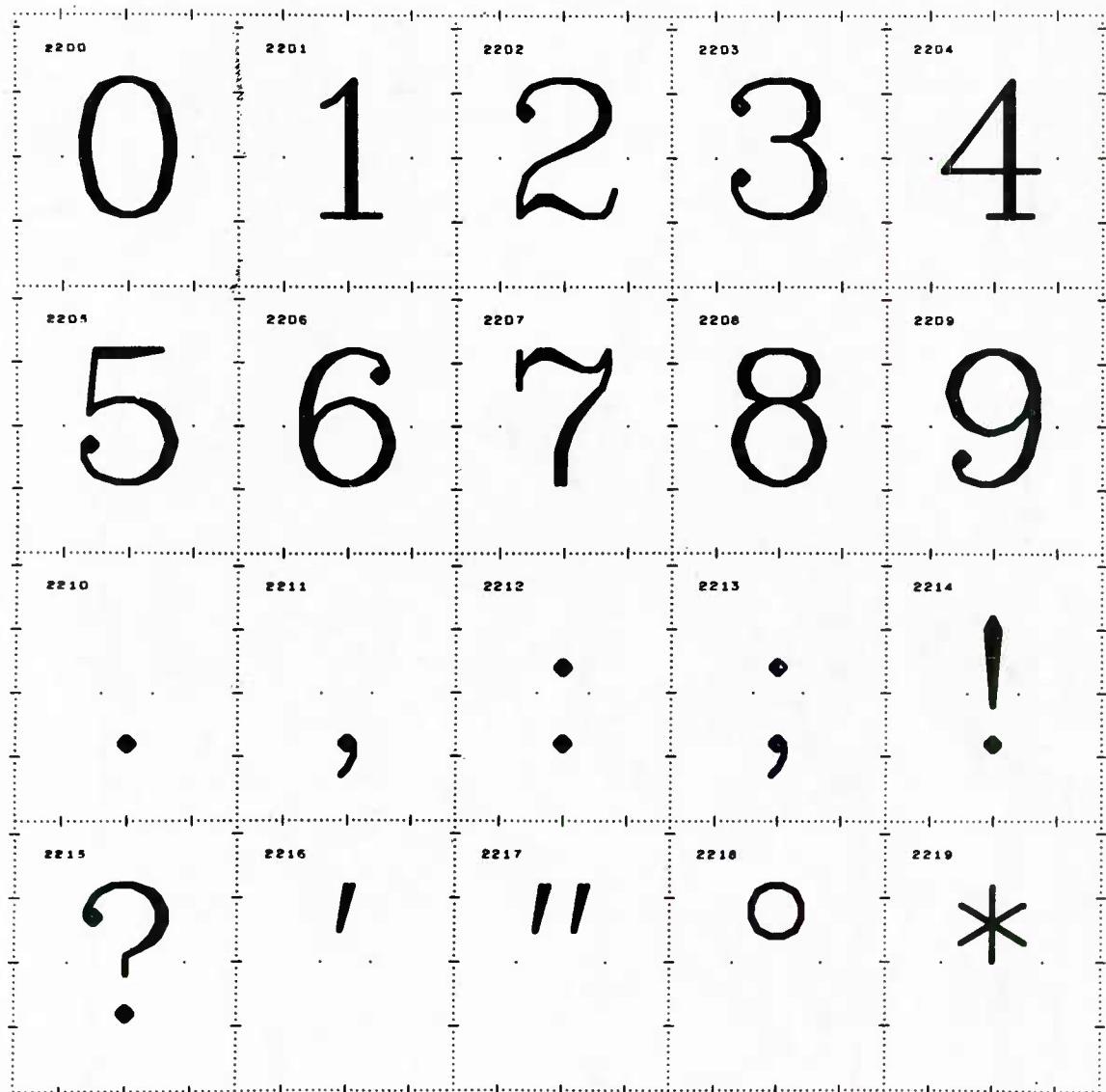
2120

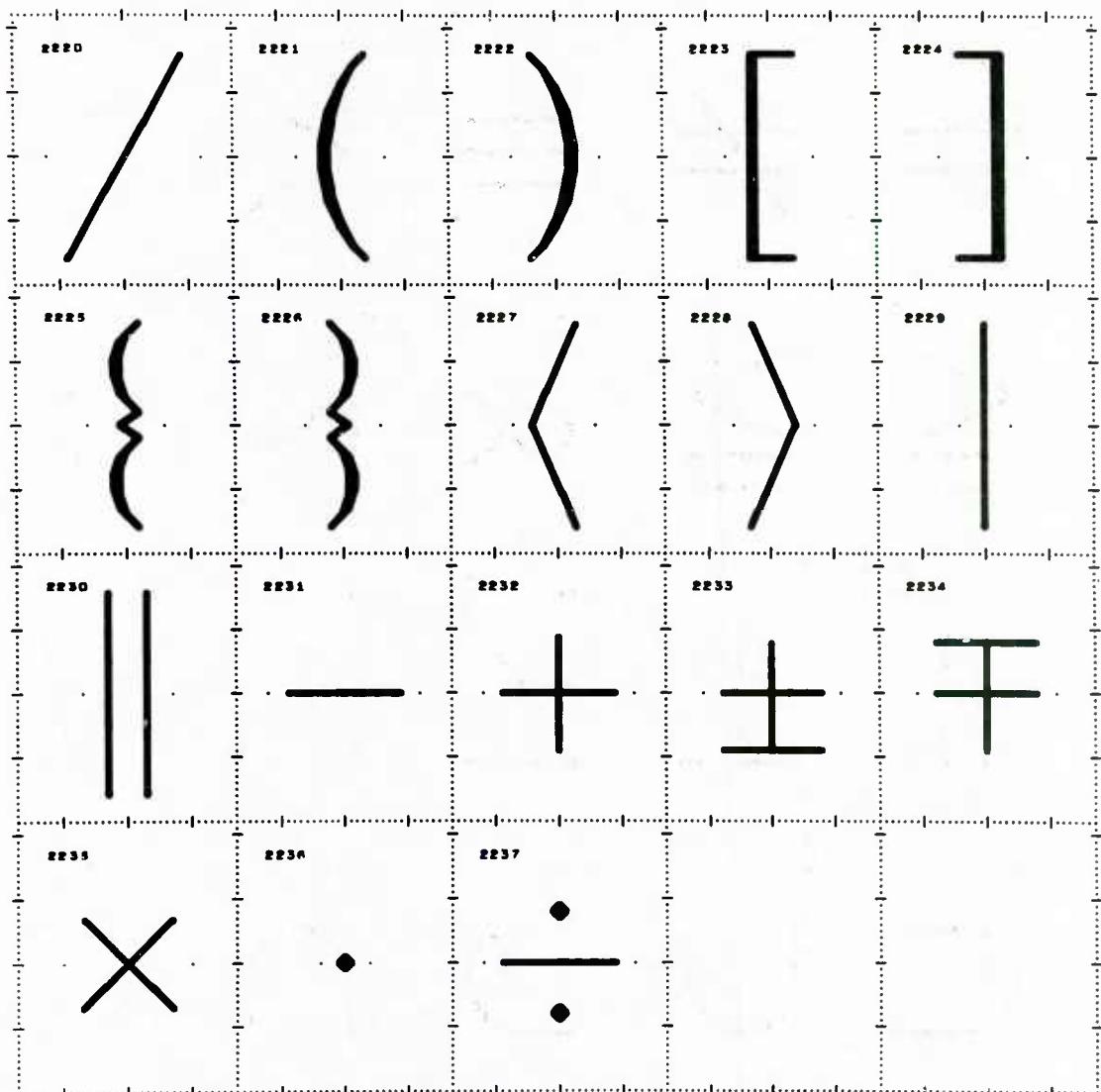
2121	2122	2123	2124	2125
u	v	w	x	y
2126	2127	2128	2129	2130
z	α	β	γ	δ
2131	2132	2133	2134	2135
ε	ζ	η	ϑ	ι
2136	2137	2138	2139	2140
κ	λ	μ	ν	ξ

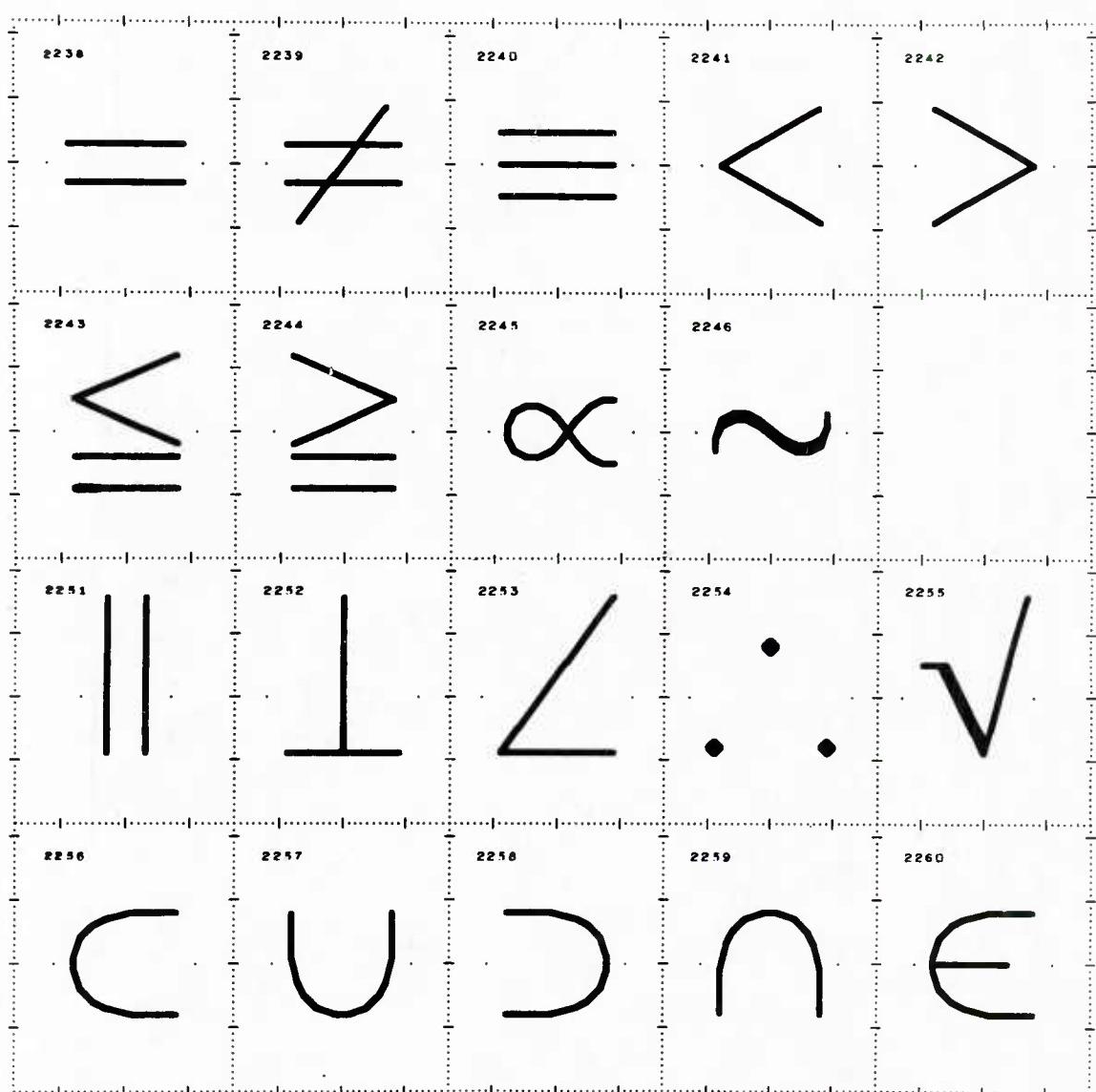
2141	2142	2143	2144	2145
O	π	ρ	σ	τ
2146	2147	2148	2149	2150
v	φ	χ	ψ	ω
2151	2152	2153	2154	2155
a	b	c	d	e
2156	2157	2158	2159	2160
f	g	h	i	j

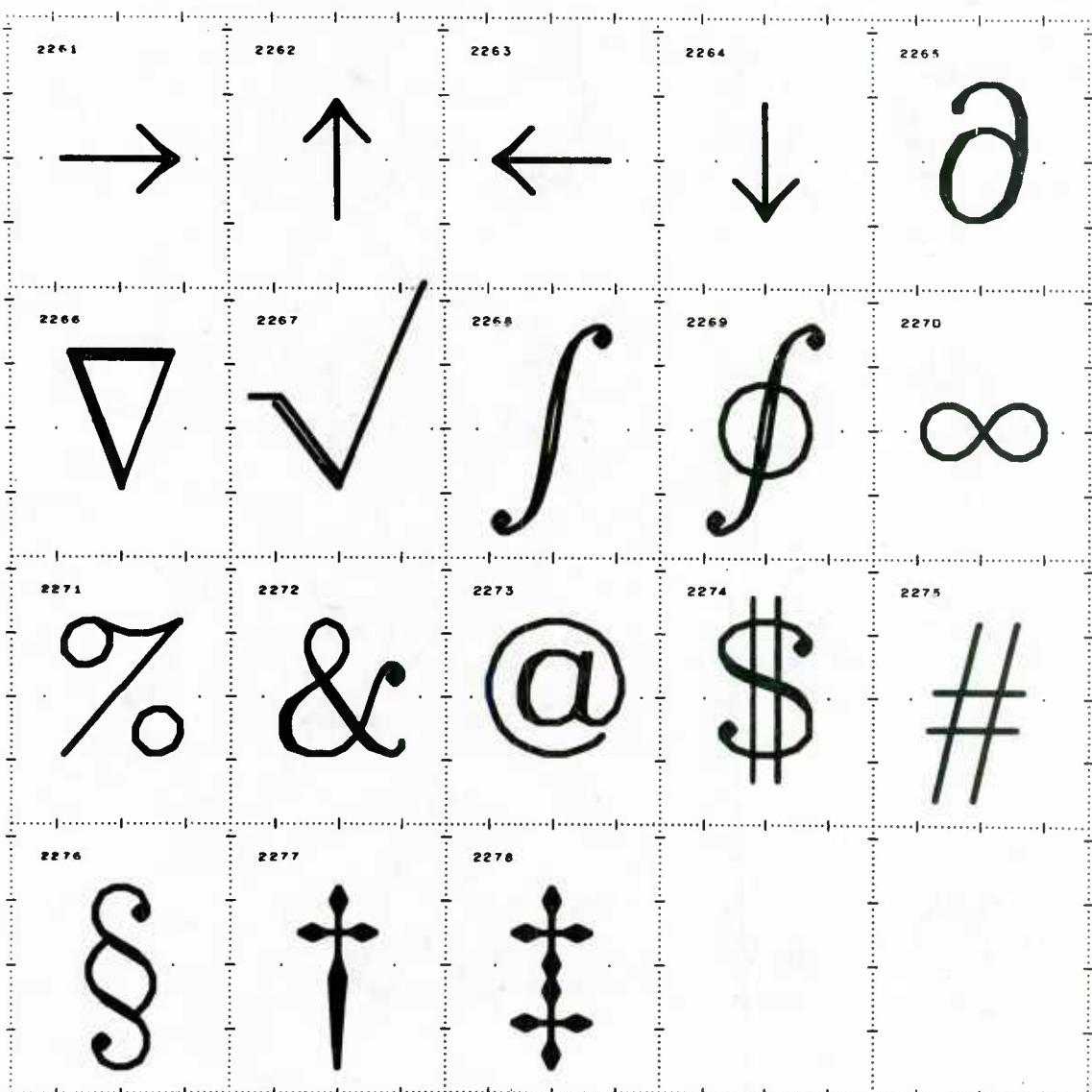


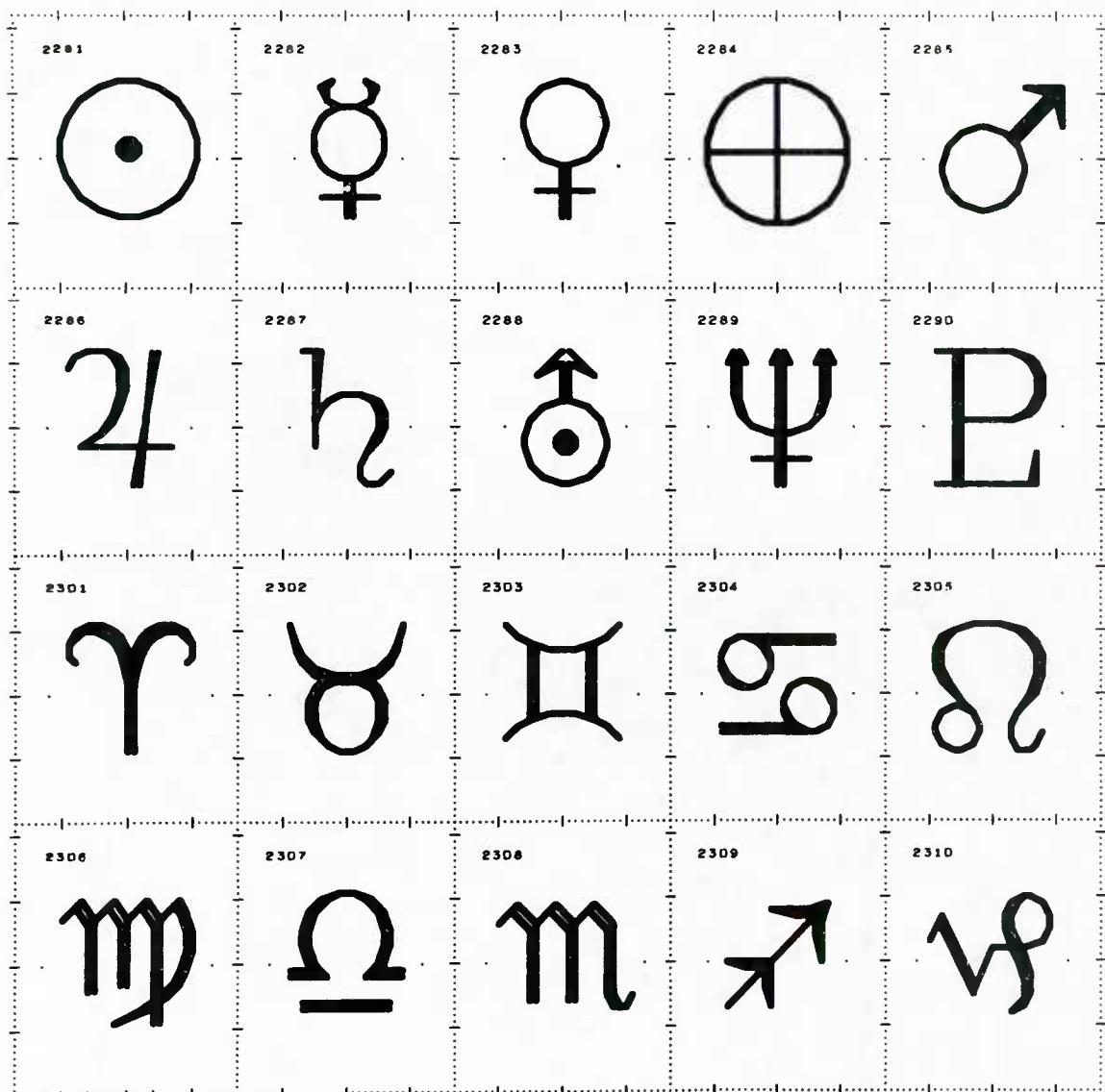


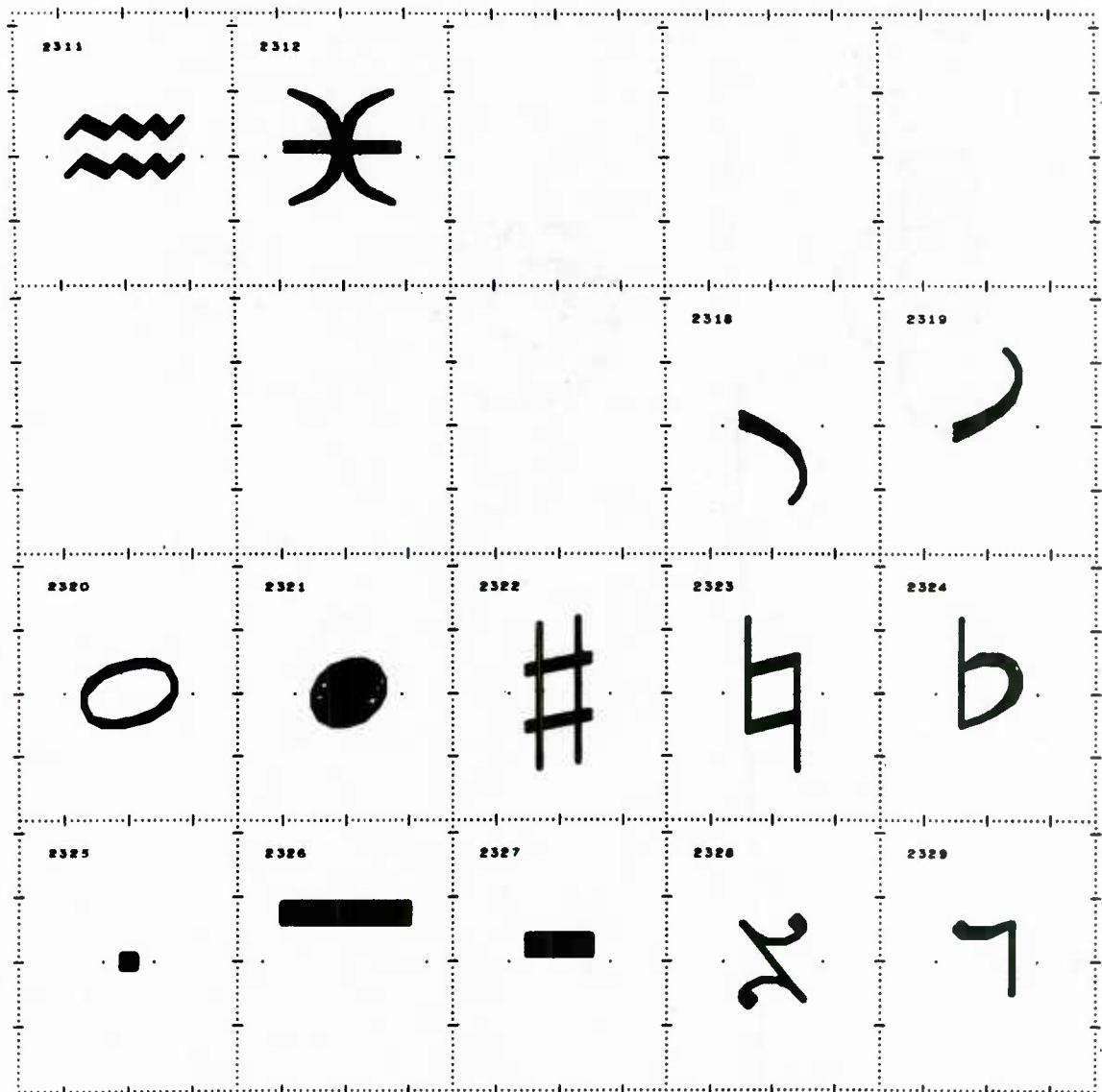


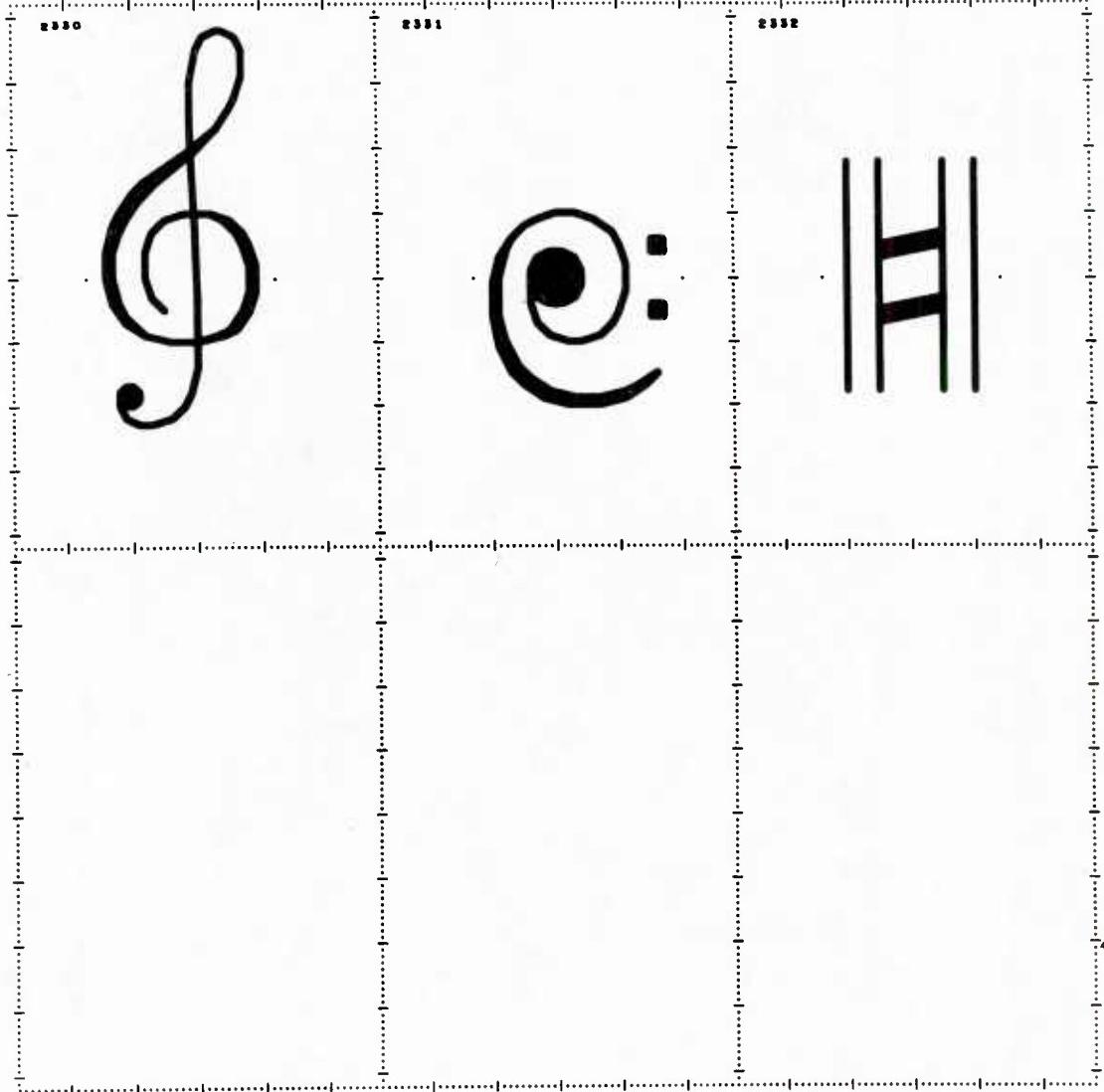


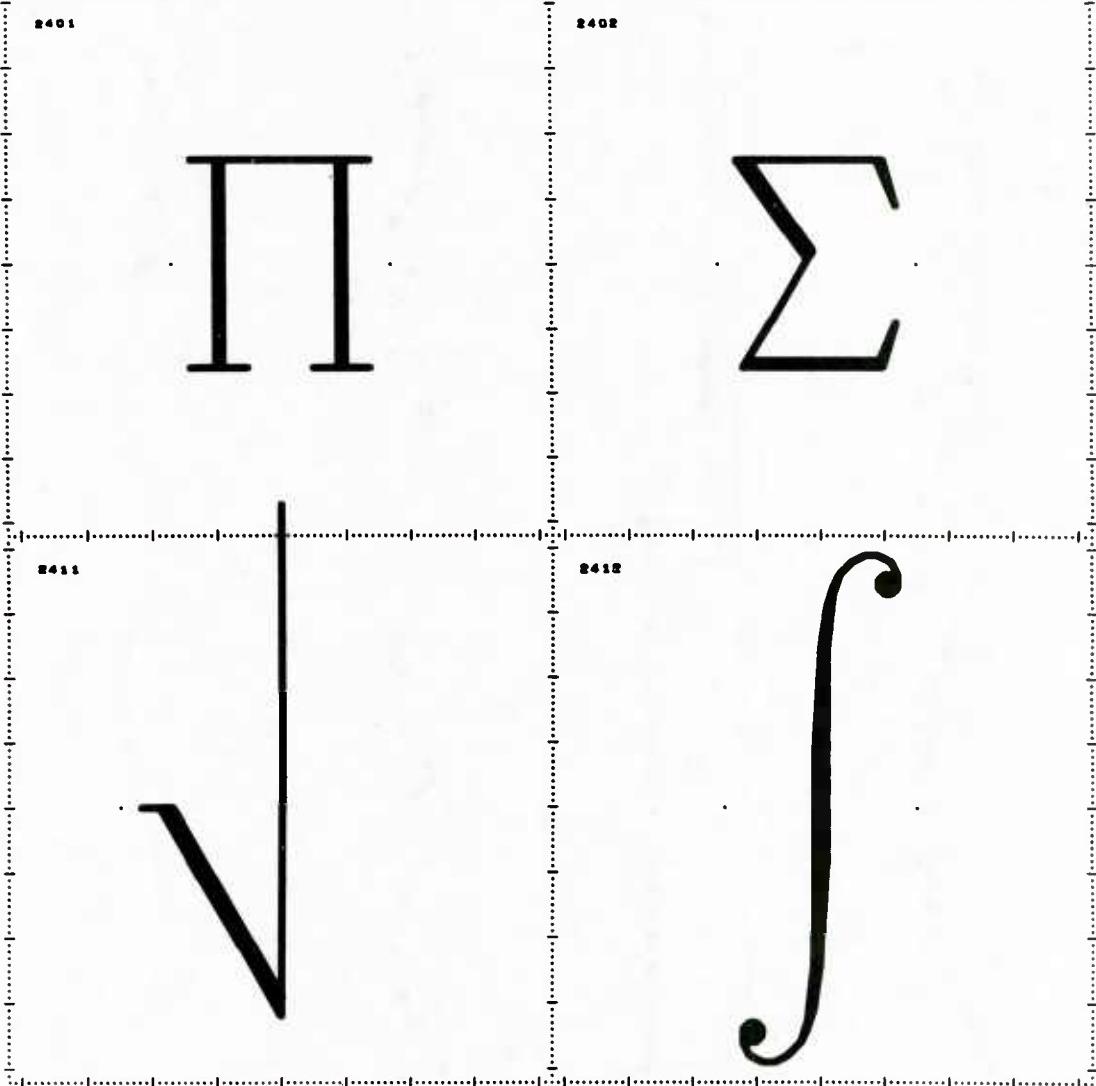


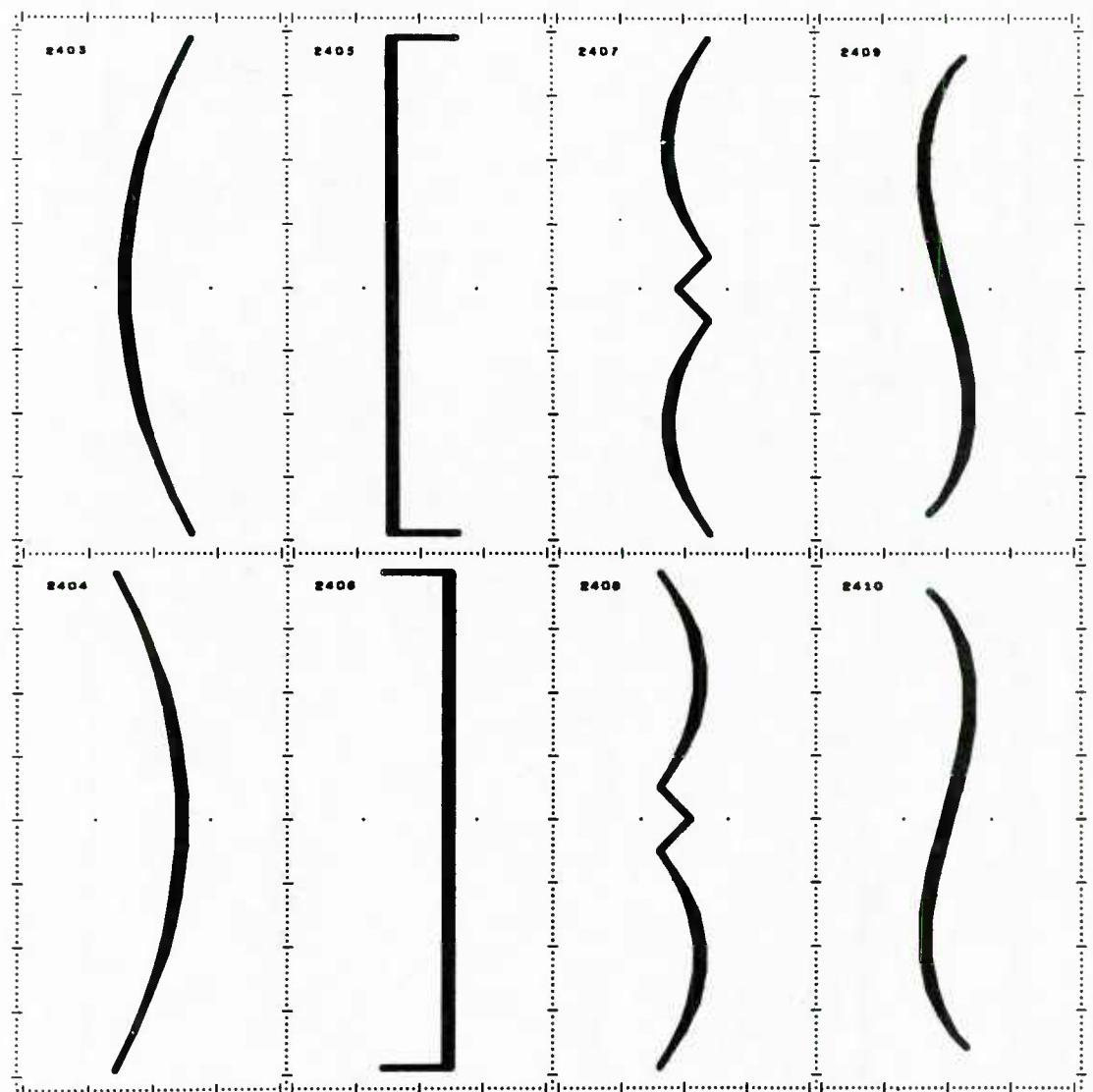


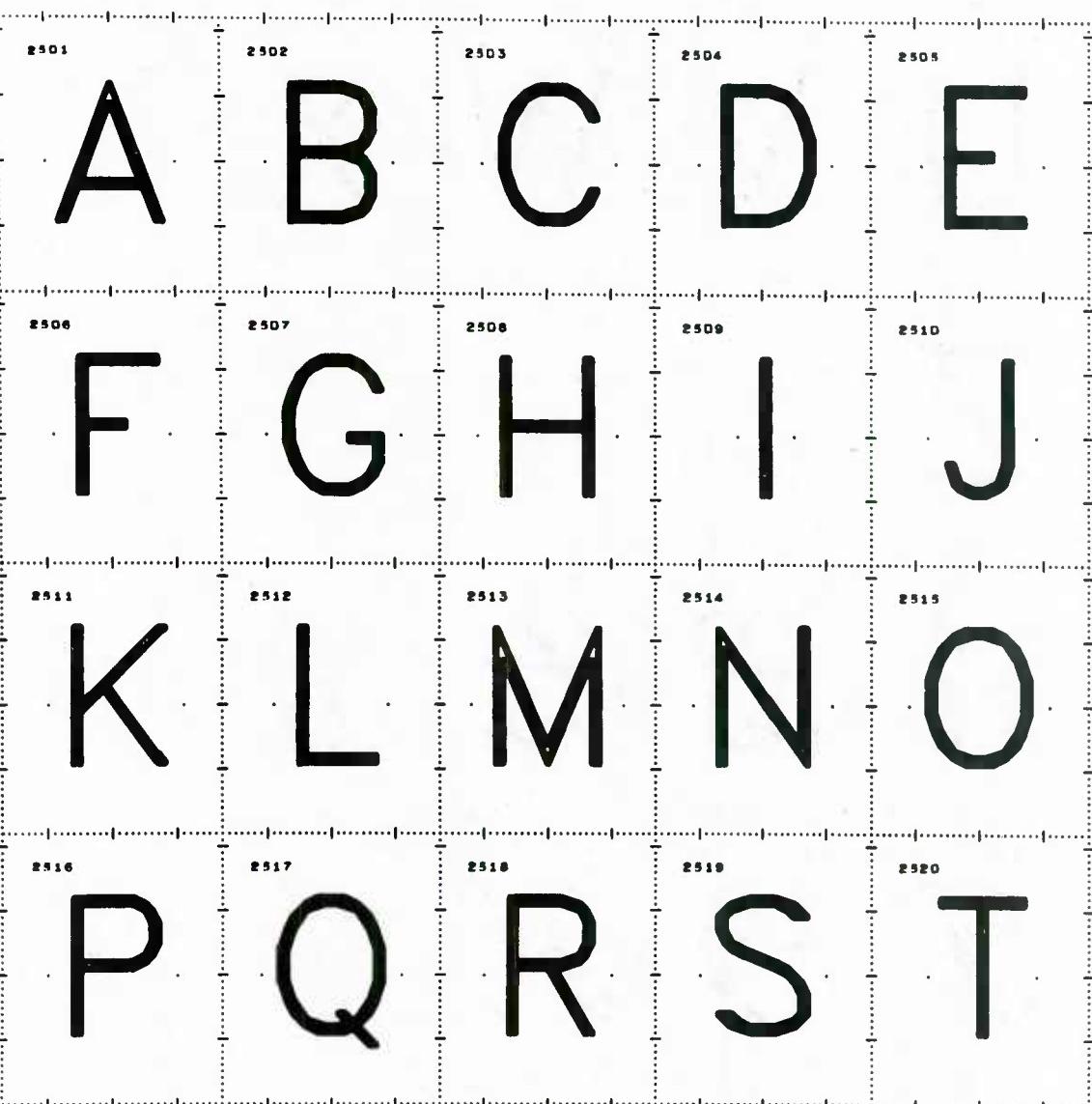


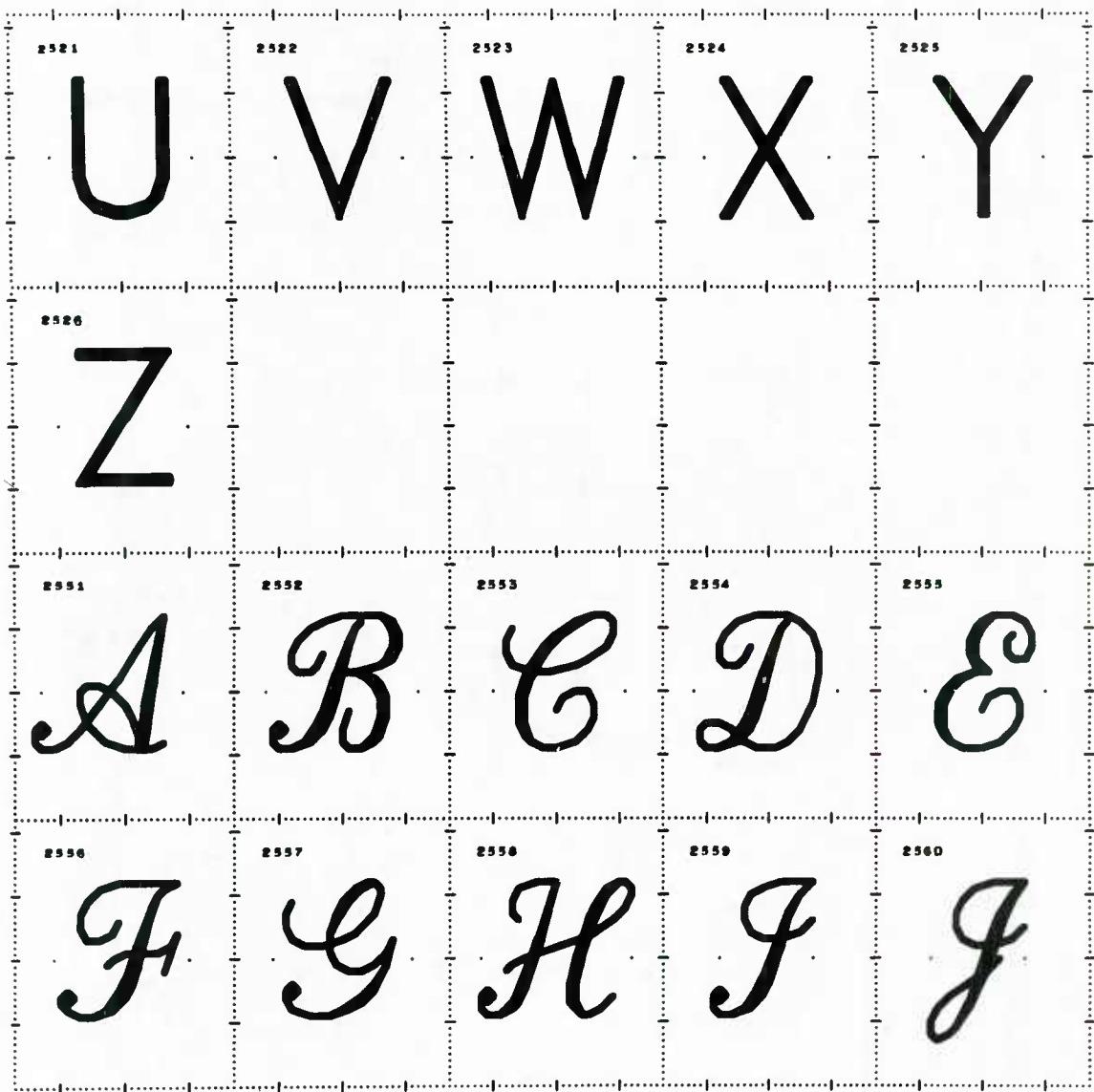










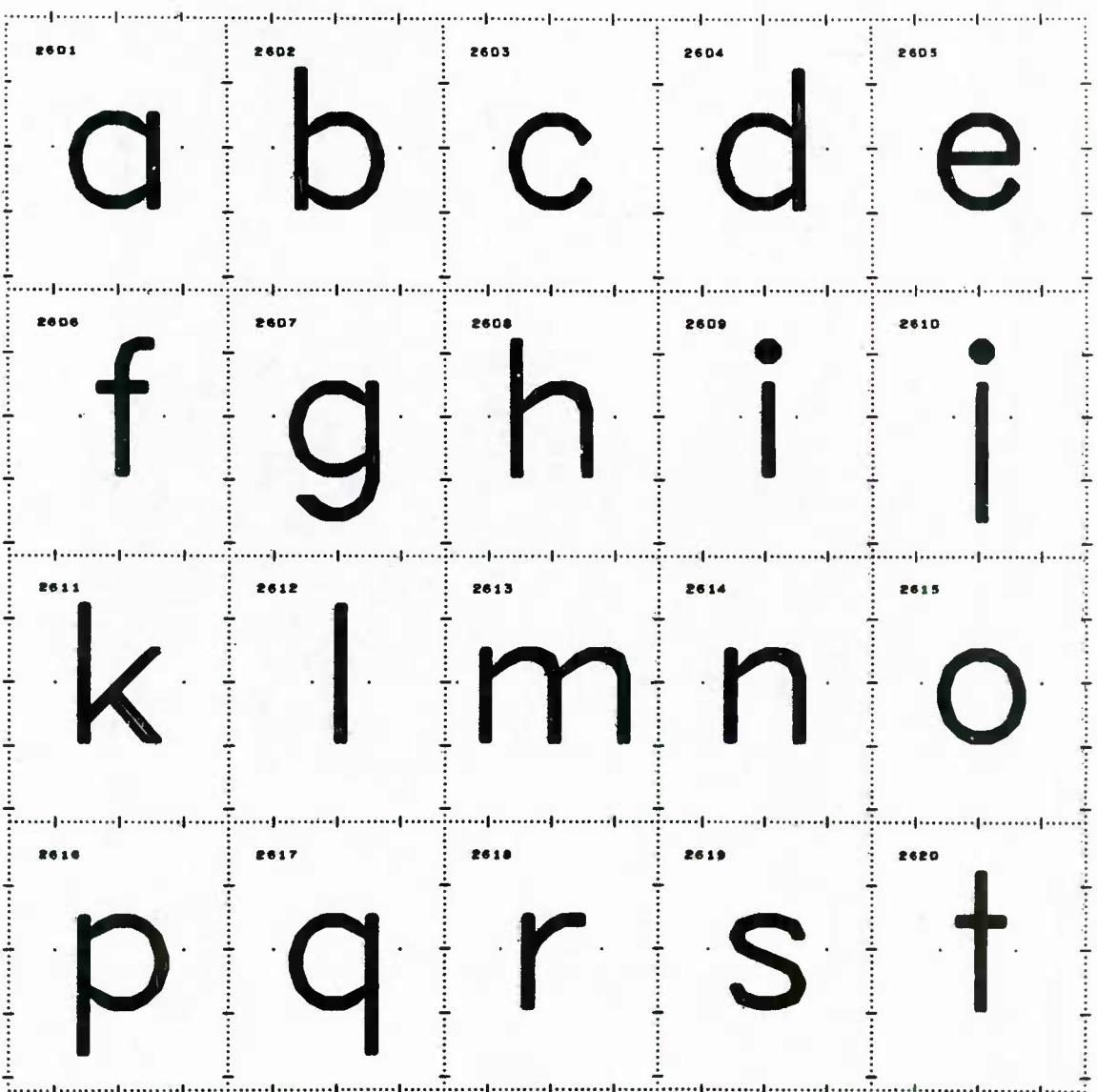


K L M N O

P Q R S T

U V W X Y

Z



2621	2622	2623	2624	2625
u	v	w	x	y
2626				
z				
2651	2652	2653	2654	2655
a	b	c	d	e
2656	2657	2658	2659	2660
f	g	h	i	j

2661	2662	2663	2664	2665
k	l	m	n	o
2666	2667	2668	2669	2670
p	q	r	s	t
2671	2672	2673	2674	2675
u	v	w	x	y
2676				
z				

2801	2802	2803	2804
А	Б	В	Г
2805	2806	2807	2808
д	Е	Ж	З
2809	2810	2811	2812
И	Й	К	Л
2813	2814	2815	2816
М	Н	О	П

P	C	T	Y
Φ	X	Ц	Ч
ІІІ	ІІІ	Ь	Ы
ъ	э	ю	я

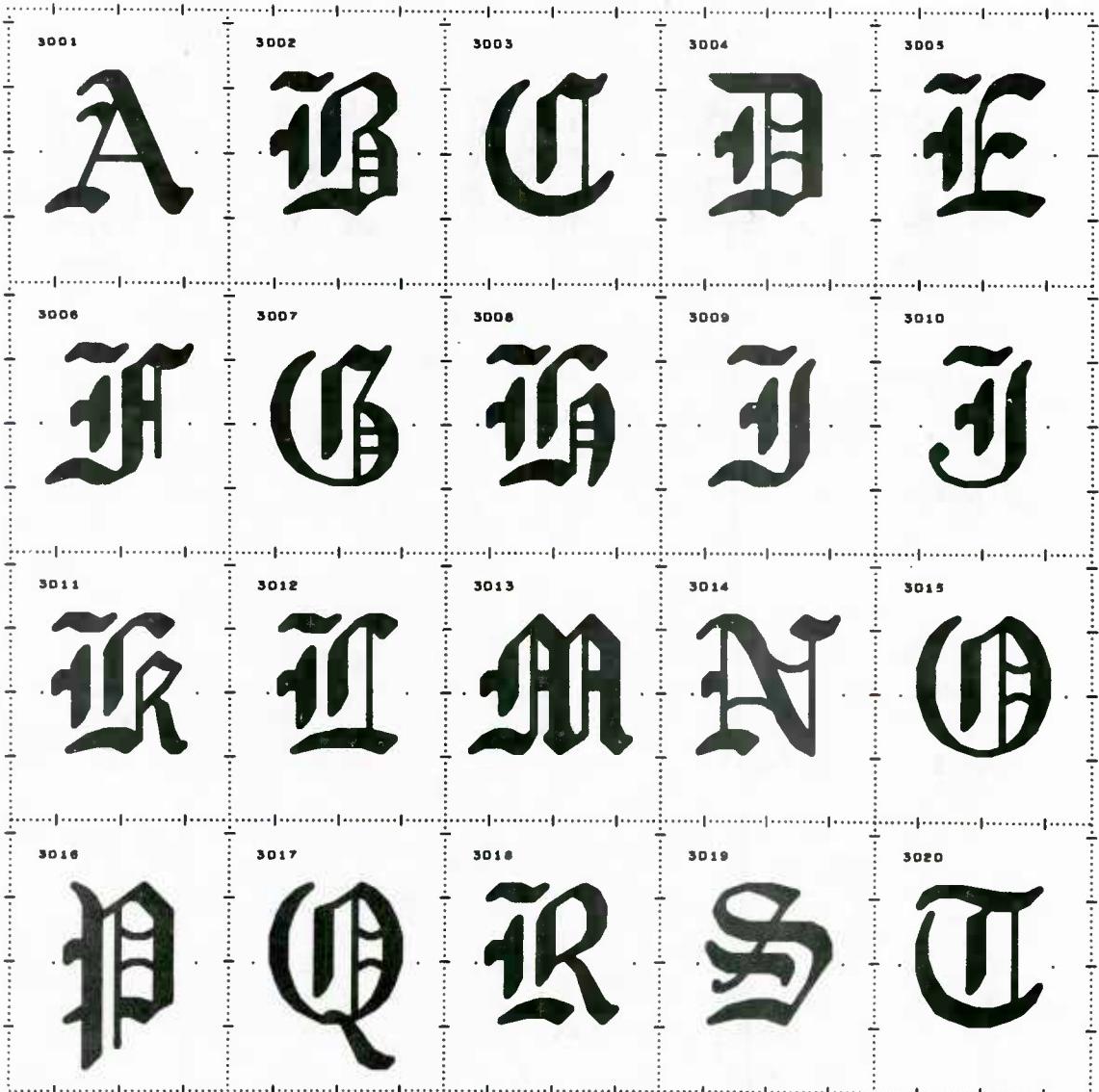
2901	2902	2903	2904
а	б	в	Г
2905	2906	2907	2908
д	е	ж	з
2909	2910	2911	2912
и	й	к	л
2913	2914	2915	2916
м	н	о	п

2917	2918	2919	2920
p	c	T	y
2921	2922	2923	2924
φ	x	ц	ч
2925	2926	2927	2928
ш	щ	ъ	ы
2929	2930	2931	2932
ъ	э	ю	я

PART III

TRIPLEX REPERTORY

- A. English Gothic
- B. Italian Gothic
- C. German Gothic



3001

3002

3003

3004

3005

3006

3007

3008

3009

3010

3011

3012

3013

3014

3015

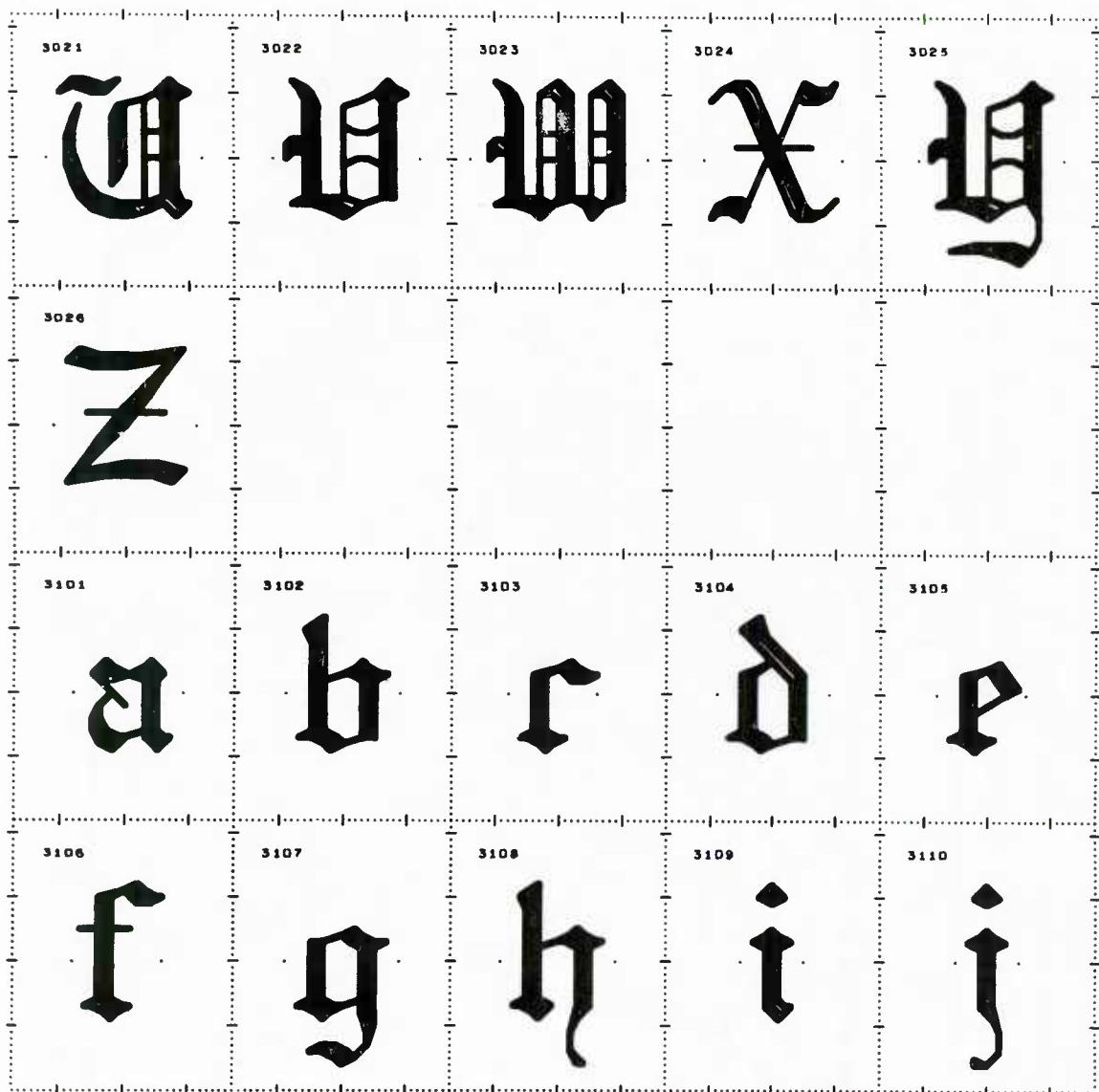
3016

3017

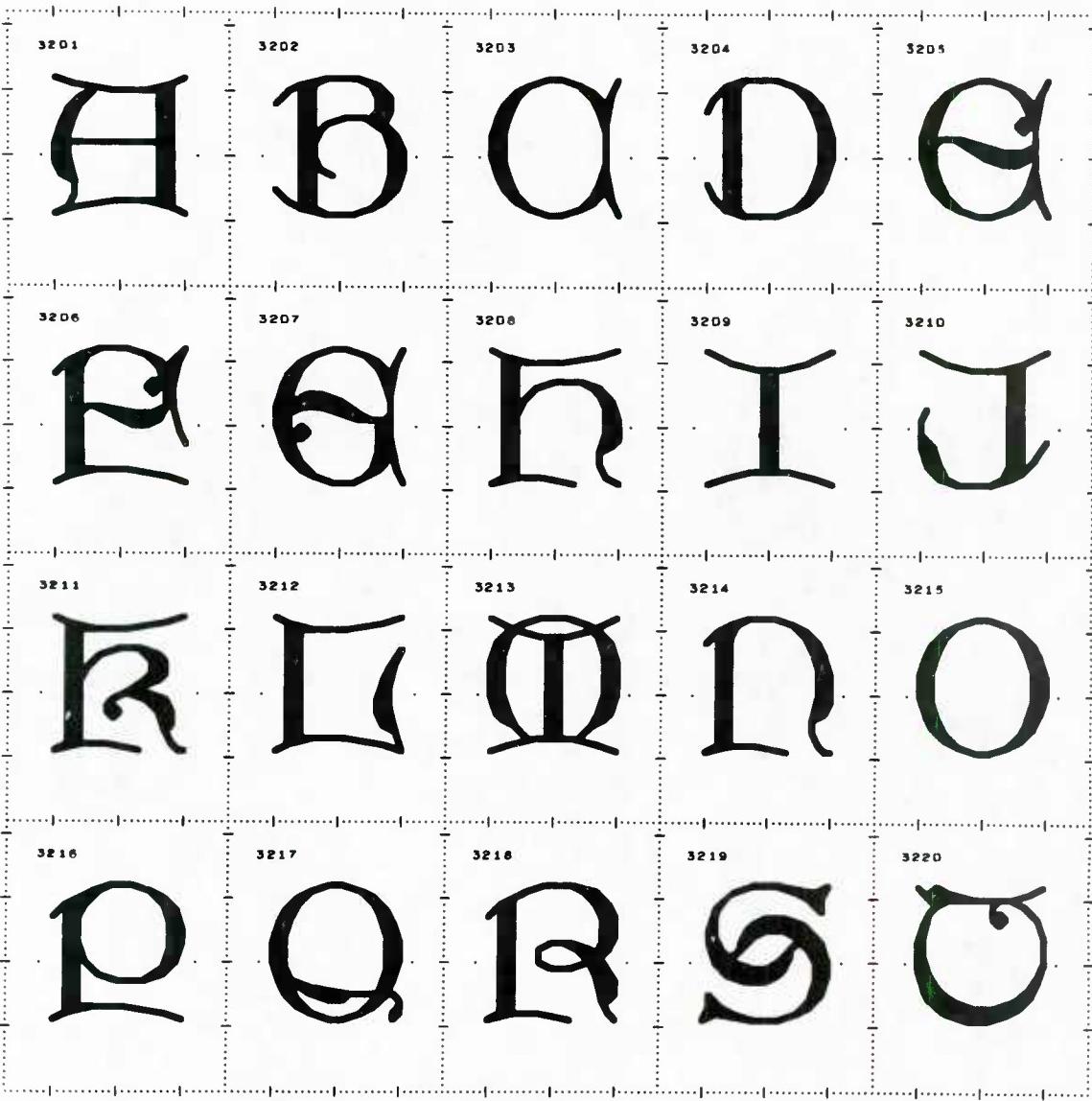
3018

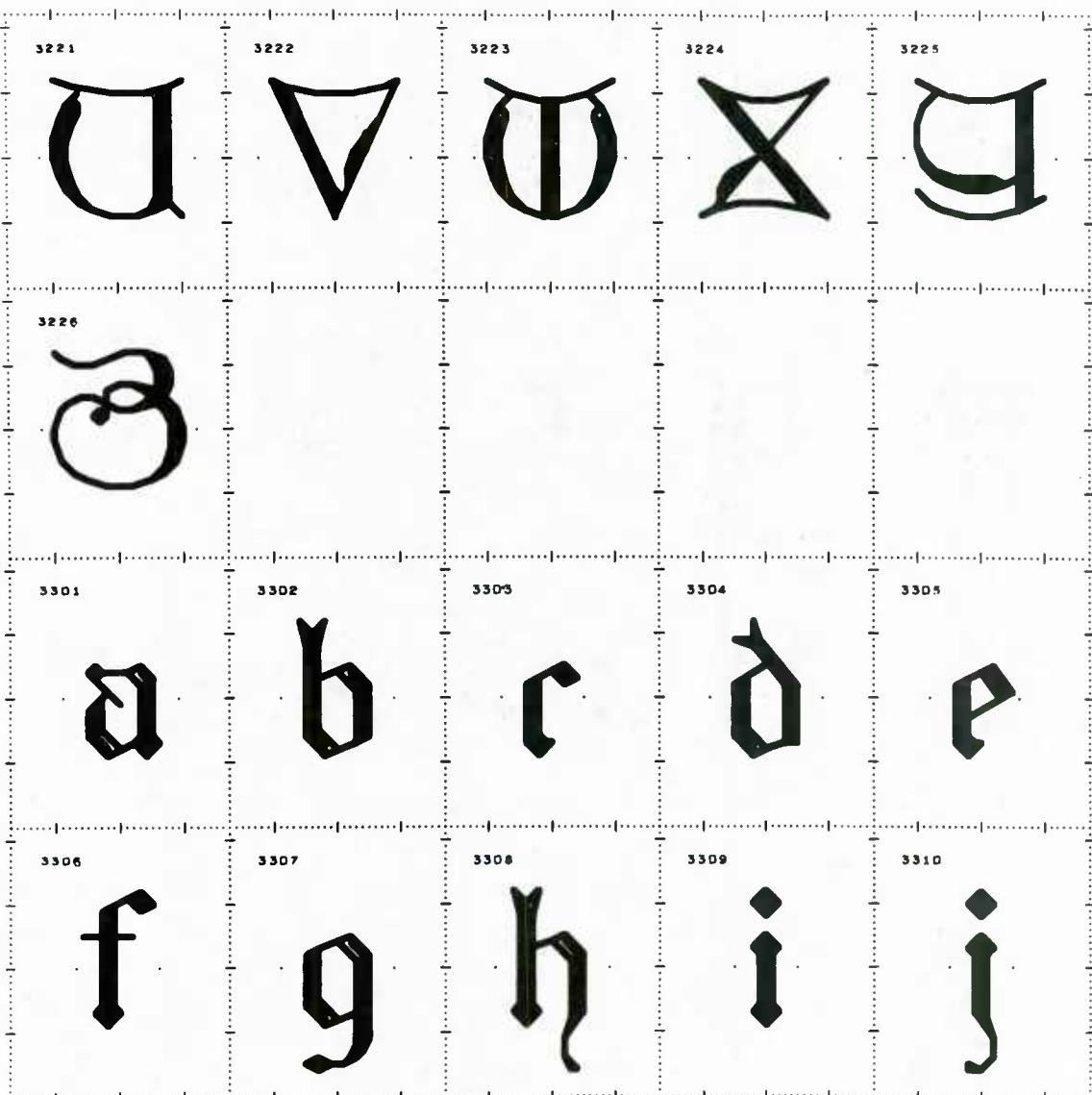
3019

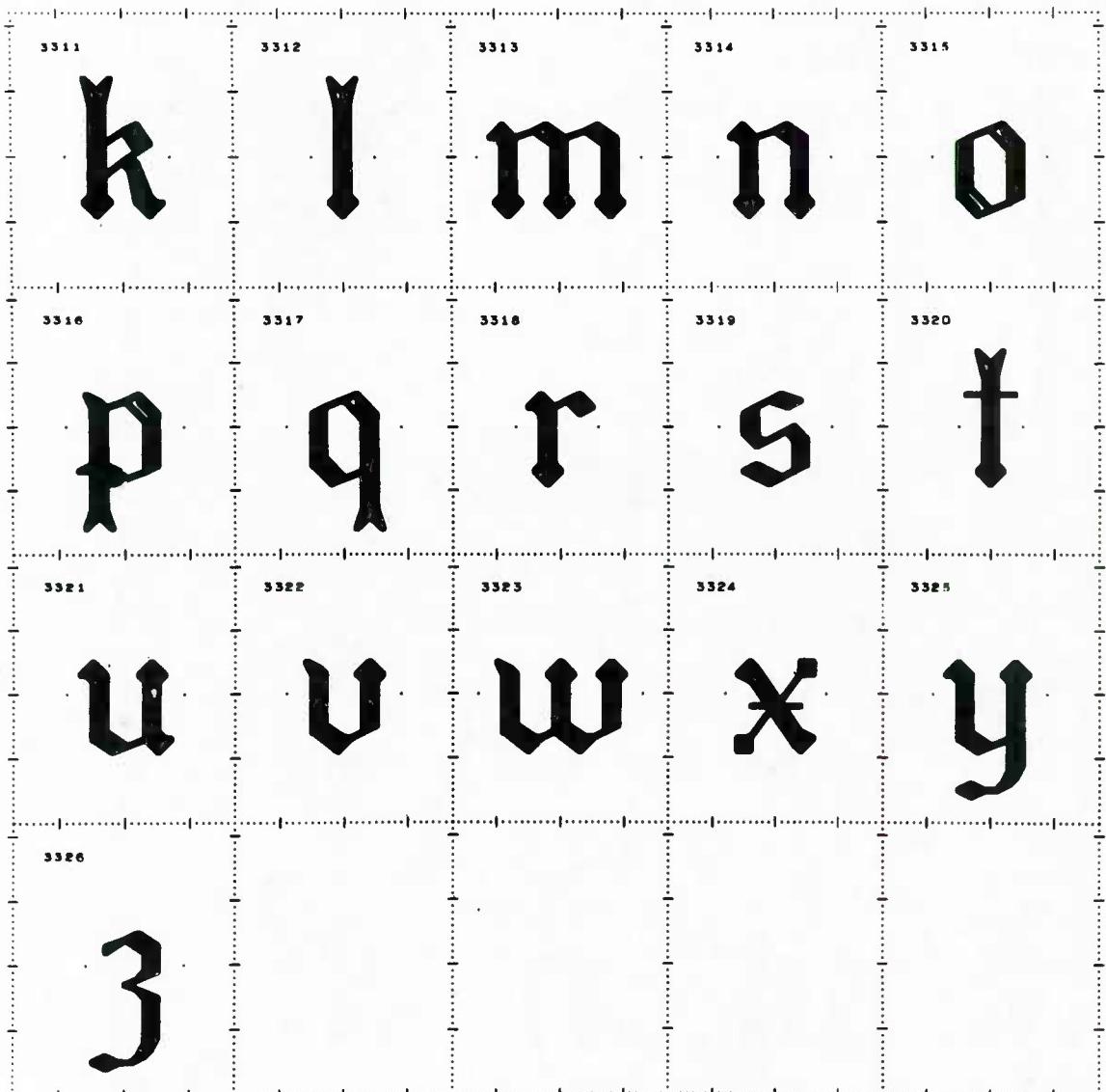
3020



3111	3112	3113	3114	3115
k	l	m	n	o
3116	3117	3118	3119	3120
p	q	r	s	t
3121	3122	3123	3124	3125
u	v	w	x	y
3126				
	z			







3401



3402



3403



3404



3405



3406



3407



3408



3409



3410



3411



3412



3413



3414



3415



3416



3417



3418



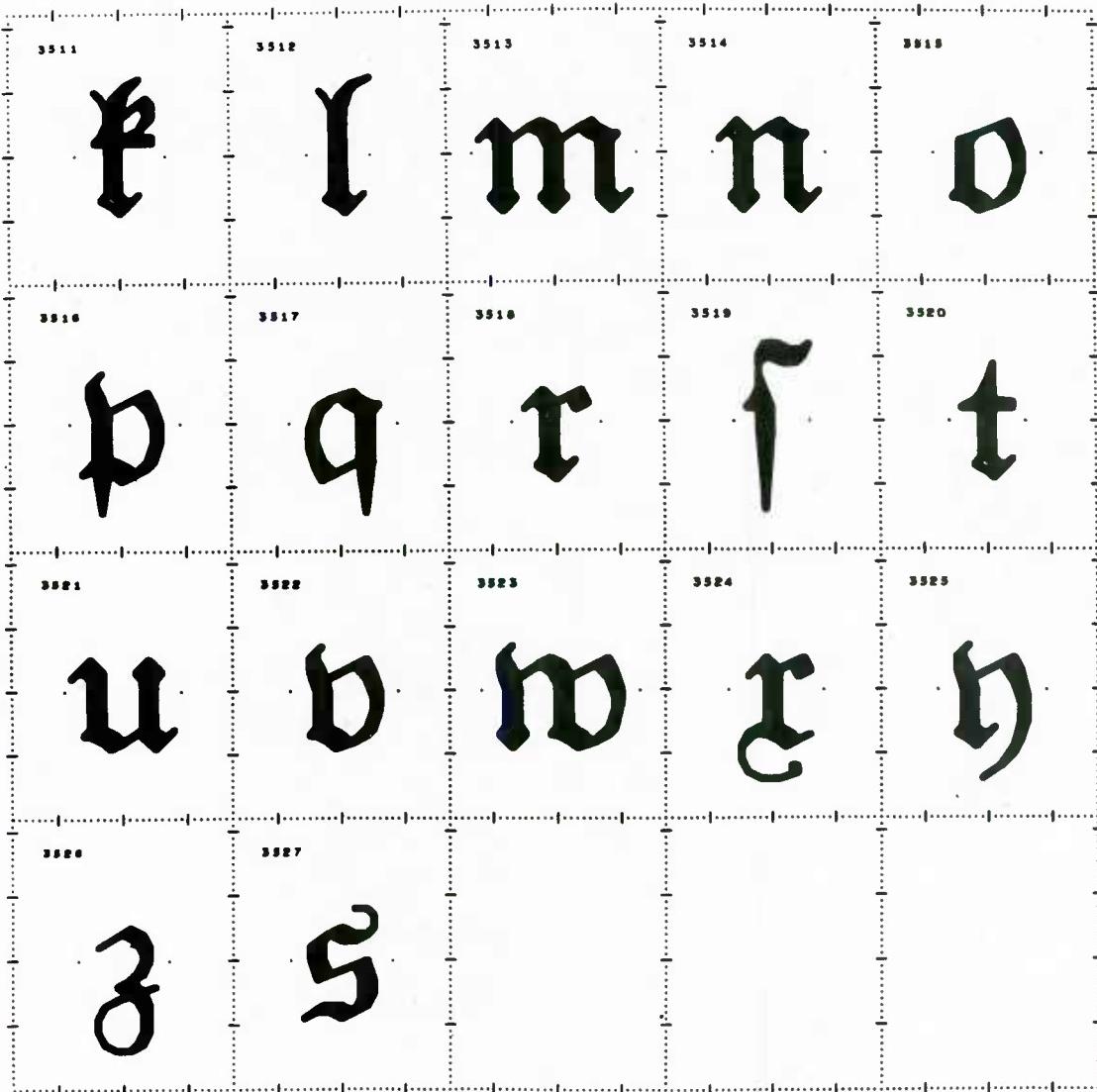
3419



3420



3421	3422	3423	3424	3425
3426				
3501	3502	3503	3504	3505
3506	3507	3508	3509	3510



APPENDIX C

DIGITALIZATION OF JAPANESE

DECK 2525

The border of each panel indicates the scale in raster units with every 10th raster unit accentuated. The number in the upper left corner is the number of the character. The words in the lower left corner are the *on* pronunciation for the *kanji* or the phonetic pronunciation for the *kana*.

PART I

KANJI LIST

0001	0007	0008	0009	0015
一 万 三 下 五	ICHIRU, ITSU	MAN, BAN	SAN	KA, GE
天 不 可 平 正	TEN	FU, BU	KOKU, KA	HYŌ, BYŌ, HEI
百 両 再 重 函	BYAKU, HYAKU	RYŌ	SAI	A
画 尽 歪 夏 惡	GA, KAKU	CHŪ	WAI, E	GE, KA
0016	0017	0024	0026	0027
0033	0034	0035	0043	0049
0050	0053	0054	0056	0062

0061 中	0082 内	0092 甲	0096 本	0097 出
CHŪ	DAI, NAI	KAN, KŌ	HON	SUI, SHUTSU
0104 向	0103 曲	0107 果	0106 表	0130 永
KŌ, KYŌ	KYOKU	KA	HYŌ	EI
0131 氷	0132 半	0138 為	0139 单	0146 九
HYŌ	HAN	I	TAN	KYŪ, KU
0154 及	0156 千	0162 午	0166 少	0173 弗
KYŪ	SEN	GO	SHŌ	FUTSU

0179 未	0188 年	0195 系	0196 束	0199 卯
MI	NEN	KEI	SOKU	RAN
0202 来	0211 垂	0213 東	0223 乘	0224 重
RAI	SUI	TŌ	JŌ	CHŌ, JŪ
0230 島	0260 乙	0261 七	0272 事	0273 二
TŌ	ITSU, OTSU	SHICHI	JI	NI, JI
0275 元	0283 六	0284 市	0285 主	0290 交
GAN, GEN	RIKU, ROKU	SHI	SU, SHŪ, SHU	KŌ

0298 夜 YA	0306 変 HEN	0319 率 SOTSU, RITSU	0321 商 SHŌ	0339 人 JIN, NIN
0350 化 KA, KE	0352 今 KIN, KON	0361 他 TA	0362 仕 SHI	0364 代 DAI
0363 合 SÖ	0384 全 ZEN	0401 位 I	0403 伸 SHIN	0405 体 TAI
0406 低 TEI	0407 作 SA, SAKU	0408 余 YO	0409 何 KA	0422 価 KA

0426 REI	0431 KYŌ, KU, GU	0449 KEI	0458 CHI	0509 SOKU
0511 HEN	0534 KEI	0540 ZŌ	0551 OKU	0571 SEN
0574 NYŪ, JU	0577 HATBU, HACHI	0578 BUN, FUN, BU	0579 KŌ, KU	0581 KYŌ
0588 TEN	0599 HEI	0590 KI	0595 SEN, ZEN	0617 EN

0619 同 DŌ	0622 周 SHŪ	0638 次 SHI, JI	0642 冷 REI	0665 刀 TŌ
0667 切 SETSU, BAI	0703 割 KATSU	0715 力 RIKI, RYOKU	0716 加 KA	0730 動 DŌ
0751 北 HOKU	0766 十 JŪ	0770 古 KO	0775 直 JIKI, CHOKU	0778 南 NAN
0783 真 SHIN	0790 卓 KAN	0791 準 JUN	0798 上 JŌ, SHŌ	0804 点 TEN

0817 反 HON, TAN, HAN	0818 庄 EN, ATSU	0825 原 GEN	0855 又 YŪ	0859 双 SŌ
0868 口 KU, KŌ	0876 右 YŪ, U	0882 号 GŌ	0885 吸 KYŪ	0913 味 MI
0923 品 MIN, HON	0931 哲 TETBU	0973 嗅 KYŪ	0994 器 KI	1025 四 SHI
1026 因 IN	1028 回 E, KAI	1034 义 TO, ZU	1036 固 KO	1037 国 KOKU

1045 卷 KEN	1050 土 TO, DO	1051 去 KYO, KO	1055 在 ZAI	1056 地 CHI, JI
1065 均 KIN	1077 型 KEI	1098 基 KI	1109 塔 TO	1113 場 JO
1125 塩 EN	1135 境 KYŌ, KEI	1137 增 ZŌ	1160 士 SHI	1161 冬 TŌ
1162 处 SHO	1163 各 KAKU	1167 夕 SEKI	1168 外 GE, GAI	1169 多 TA

1170 名 HYŌ, MEI	1171 大 TAI, DAI	1172 太 TAI, TA	1185 女 JO, NYO, NYŌ	1189 如 JO, NYO
1208 始 SHI	1264 子 SHI, SU	1267 存 SON, ZON	1271 学 GAKU	1280 宇 U
1281 字 JI	1291 宙 CHŪ	1296 定 TEI, JŌ	1297 実 JITSU	1300 室 SHITSU
1311 家 KAI, KE	1316 密 MITSU	1322 寒 KAN	1354 導 DŌ	1355 小 SHŌ

1358 KŌ	1359 TŌ	1364 JŌ, SHŌ	1377 SEKI, SHAKU	1383 BI
1386 KUTSU	1387 KO, KYO	1402 SŌ	1407 SAN	1418 TAN
1431 RAN	1447 SEN	1451 KU, KŌ	1455 SA	1459 KŌ
1466 KEN, KAN	1468 FU	1469 HAN	1484 FUKU	1492 KAN

1496 KI	1504 Ö	1508 TEI	1511 DO, TAKU, TO	1514 TEI
1515 ZA	1556 SHIKI	1560 KYÜ	1562 IN	1567 KO
1568 GEN	1573 KYÖ, GÖ	1575 DAN	1582 KI	1589 GYÖ, KEI
1598 EKI	1602 KEI	1604 HI	1610 GO, KÖ	1613 SHÖ, JU, JÜ

1614 徒	1621 術	1626 御	1631 微	1638 衝
TO	JUTSU	GO, GYO	BI, HI	SHÔ
1641 衡	1645 心	1666 性	1683 恒	1710 惑
KÔ	SHIN	SEI, SHÔ	KÔ	WAKU
1726 想	1731 感	1743 態	1756 慣	1794 戈
SÔ	KAN	TAI	KAN	KA
1799 成	1802 或	1817 戶	1823 扇	1827 手
SEI, JÔ	WAKU, KOKU	KO	SEN	SHU

1855 SETSU	1885 Ö	1903 JI	1904 SHI	1914 TEI, CHŌ
1920 SHIN	1942 REI, RETSU	1951 SETSU	1987 TEKI	2039 SHI
2044 KO	2052 KYŌ	2056 SAN	2057 SAKU, SOKU, SU, SŪ	2064 HON, BUN
2067 TAI	2074 SHA	2080 SHIN	2082 HŌ	2083 O

2084 放	2097 日	2100 早	2107 易	2108 昔
HŌ	JITSU, NICHÌ, NITSU	SA, SŌ, SATSU	EKI, I	SHAKU, SEKI
2110 明	2119 昨	2121 星	2122 春	2126 時
MEI, HYŌ, MIN	SAKU	SEI, SHŌ	SHUN	JI
2137 晶	2138 暑	2141 量	2143 晴	2146 最
SHŌ	SHŌ	RYŌ	SEI	SAI
2154 暗	2160 雲	2164 題	2169 月	2170 木
AN	DON	DAI	GETSU, GATSU	BOKU, MOKU

2194 SEKI	2210 RIN	2211 SHI, KI	2212 SHŌ	2233 RYŪ
2236 CHŪ	2241 SŌ, SHŌ	2254 KAKU	2256 Ō	2261 KON
2264 KAI	2301 SHIN	2303 SHOKU	2305 KYOKU, GOKU	2313 DA
2324 RAKU, GAKU	2343 KŌ	2359 HYŌ	2361 Ō	2376 KYŌ

2379	2412	2429	2430	2435
KI	KETSU	SHI	SHI	SHI
2436	2438	2439	2466	2467
SEI	RETSU	SHI	BO	MAI
2470	2473	2478	2480	2482
HI	HŌ	SHI	KI, KE	SUI
2503	2507	2509	2529	2530
TAKU	KI	KETSU	HA	KA

機 欠 止 此 雌
整 列 死 母 每
比 毛 氏 氣 水
沢 汽 決 波 河

2534 油 YU, YŪ	2535 法 HŌ	2553 海 KAI	2565 涌 YŌ, YU	2573 酒 SHU
2576 流 RYŪ	2599 液 EKI	2629 渦 KA	2631 湿 SHITSU	2632 測 SOKU
2634 温 ON	2637 減 GEN	2655 淹 RŌ, SŌ	2656 源 GEN	2659 溶 YŌ
2702 潮 CHŌ	2743 火 KO, KA	2745 灯 TEI, CHŌ, TŌ	2750 炉 RO	2770 然 ZEN, NEN

2772 SHŌ	2773 HU, SU	2797 NETSU	2807 RIN	2808 NEN
2829 AI	2832 FU	2839 JŌ	2842 HEN	2848 GAI, GE
2852 GO, GYŪ	2857 BUTSU, MOTSU	2860 TOKU	2868 KEN	2872 Ō
2823 GYOKU	2937 KEI	2941 KYŪ	2942 RI	2943 GEN
2845 RAN	2846 TSU	2847 TSU	2848 TSU	2849 TSU

2973 瓜 KA	2977 瓦 GA	2988 甘 KAN	2991 生 SHŌ, SEI	2993 用 YŌ
2994 田 DEN	2995 男 DAN, NAN	2996 界 KAI	3001 思 SHI	3008 異 I
3042 病 BYŌ, HEI	3092 發 HOTSU, HATSU	3095 白 HAKU, BYAKU	3107 的 TEKI	3109 皮 HI
3113 皿 BEI, NYŌ	3127 目 HOKU	3128 具 GU	3164 矛 MU, BŌ	3168 矢 SHI

3169 CHI	3172 TAN	3176 SEKI, SHAKU	3180 KEN	3191 RYŪ
3192 SHŌ	3200 HŌ	3209 JÌ	3226 JÌ, SHI	3264 RÌ
3265 SHÌ	3268 KAI, WA	3271 BYŌ	3272 KA	3273 SHŪ
3275 SHŌ	3280 SHŌ	3285 TEI	3294 TŌ	3295 SHŪ

3306 SEKI	3313 KETSU	3314 KYŪ	3317 KŪ	3325 CHITSU
3343 RYŪ, RITSU	3366 CHIKU	3385 TEI, DAI	3396 TŌ	3397 HITSU
3415 SAN	3416 KAN	3458 RŌ	3461 BEI, MAI	3466 RYŌ
3471 RYŪ	3472 NEN	3492 SHI	3496 KYŪ	3509 JUN

3510 紙 SHI	3511 素 SO, SU	3520 組 SO	3521 終 SHŪ	3522 細 SAI
3523 経 KEI, KYŌ	3537 絵 KAI	3539 絶 ZETSU	3540 結 KETSU	3545 絹 KEN
3544 続 ZOKU	3567 総 SŌ	3579 緯 I	3580 線 SEN	3581 締 TEI
3597 縱 SHŌ, JŪ	3644 置 CHI	3656 羊 YŌ	3658 美 BI	3662 差 SHI, SA

3665 着	3673 羽	3676 翠	3680 翼	3683 老
CHAKU	U	SUI	YOKU	RÖ
3684 考	3685 者	3697 耳	3699 取	3719 書
KŌ	SHA	JI	SHU	SHO
3724 肉	3727 有	3749 胞	3785 期	3788 朝
NIKU	YŪ, U	HŌ	KI, GO	CHŌ
3837 臣	3841 自	3845 至	3855 舌	3856 乱
SHIN	SHI, JI	SHI	ZETSU	RAN, RON

3860	3863	3865	3873	3884
辭	舟	般	船	良
JI	SHŪ	HAN	SEN	RYŌ
3888	3893	3895	3898	3940
色	花	若	草	茶
SHOKU, SHIKI	KE, KA	JAKU, NYA	SŌ	SA, CHA
3896	3901	4001	4002	4074
荷	菊	葉	蒸	菜
KA	KIRU	YŌ	JŌ, SHŌ	YAKU
4108	4115	4205	4213	4214
虛	虫	血	行	衣
KYO, KO	CHŪ	KETSU	AN, KŌ, GYŌ	E, I

4234 裝 sō, shō	4255 複 fuku	4273 西 sei, sai	4274 要 yō	4284 見 ken, gen
4301 角 kaku	4306 解 ge, kai	4309 言 gen, gon	4312 計 kei	4318 記 ki
4341 証 shō	4358 話 wa	4374 語 go, gyo	4375 讀 toku, doku	4384 誰 sui
4391 論 ron	4438 谷 koku	4465 豆 tō, zu	4472 象 shō, zō	4486 貝 bai

4488 負	4518 質	4534 赤	4539 走	4543 超
FU	SHITSU	SEKI, SHAKU	SŌ	CHŌ
4546 足	4548 距	4561 路	4601 身	4603 射
BUKU	KYO	RO	SHIN	SHA
4608 車	4610 軌	4615 転	4619 軸	4620 輕
SHA	KI	TEN	JIKU	KEI
4623 較	4630 輪	4633 幅	4646 辛	4660 込
KAKU, KŌ	RIN,	FUKU	SHIN	

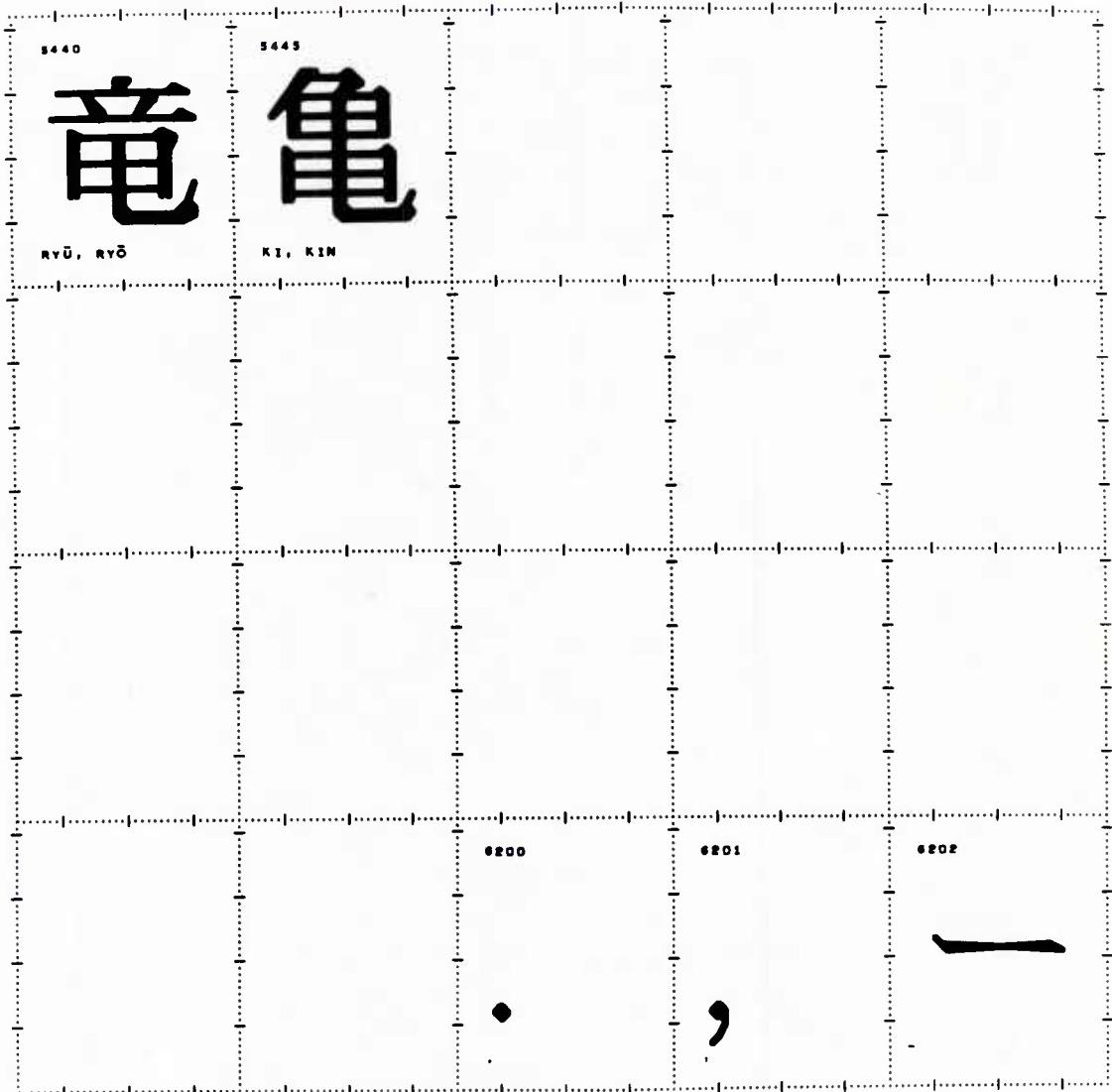
4661 HEN	4671 KIN	4685 GYAKU, GEKI	4700 SOKU	4701 ZŌ
4702 REN	4703 TSU, TŌ, TSŪ	4709 SHIN	4721 TATSU	4722 CHI
4723 KA	4724 DŌ	4725 UN	4733 EN, ON	4750 KAN, GEN
4789 SAN	4796 SHŪ	4809 SHAKU, SEKI	4811 BAN	4813 RI

辺 近 逆 速 造
連 通 進 達 暫
過 道 運 遠 還
酸 醜 累 番 里

4815 金 KON, KIN	4843 鉱 KÔ	4844 鉄 TETSU	4853 銅 DOÔ	4855 銀 GIN
4883 鋼 KÔ	4938 長 CHÔ	4940 門 MON	4944 間 MON	4945 閉 HEI
4949 間 KAN	4950 開 KAI	4958 閑 KAN	4959 聞 BUN, MON	4967 限 GEN
4993 除 JI, JO	4994 降 KÔ	5005 陸 ROKU, RIKU	5006 陰 ON, AN, IN	5012 陽 YÔ

5030 雄	5038 難	5040 離	5042 雨	5044 雪
YŪ	NAN	RI	U	SETSU
5046 雲	5048 零	5049 雷	5050 電	5055 震
UN	REI	RAI	DEN	SHIN
5056 靈	5076 青	5077 靜	5080 非	5083 翡
REI, RYŌ	SEI, SHŌ	JŌ, SEI	HI	HI
5087 面	5088 革	5110 音	5136 類	5148 風
MEN	KAKU	ON, IN	RUI	FU, FŪ

5152 飛 HI	5154 食 SHI, JIKI, SHOKU	5166 首 SHU	5188 香 KŌ	5193 馬 HE, BA, MA
5220 驗 KEN, GEN	5236 骨 KOTSU	5248 高 KŌ	5276 鬼 KI	5281 魚 GYO
5340 鳥 CHŌ	5375 鹿 ROKU	5385 麦 BAKU	5390 麻 MA	5399 黃 KŌ, Ō
5403 黑 KOKU	5404 墨 BOKU	5415 鼓 KO	5421 鼻 BI	5428 齒 SHI



PART II

HIRAGANA LIST

6000	6001	6002	6003	6004
あ	い	う	え	お
A	I	U	E	O
6005	6006	6007	6008	6009
か	き	く	け	こ
KA	KI	KU	KE	KO
6010	6011	6012	6013	6014
さ	し	す	せ	そ
SA	SHI	SU	SE	SO
6015	6016	6017	6018	6019
た	ち	つ	て	と
TA	CHI	TSU	TE	TO

6020	6021	6022	6023	6024
NA	NI	NU	NE	NO
は	ひ	ふ	へ	ほ
HA	HI	FU	HE	HO
6030	6031	6032	6033	6034
ま	み	む	め	も
MA	MI	MU	ME	MO
6035	6036	6037	6038	6039
や	い	ゆ	え	よ
YA	JI	YU	YE	YO

6040	6041	6042	6043	6044
ら	り	る	れ	ろ
RA	RI	RU	RE	RO
6045	6046	6047	6048	6049
わ	ゐ	う	ゑ	を
WA	WI	WU	WE	WO
6050				
ん				
N				
6055	6056	6057	6058	6059
が	ぎ	ぐ	げ	ご
GA	GI	GU	GE	GO

6060	6061	6062	6063	6064
ざ	じ	ず	ぜ	ぞ
ZA	JI	ZU	ZE	ZO
6065	6066	6067	6068	6069
だ	ぢ	づ	で	ど
DA	JI	ZU	DE	DO
6070	6071	6072	6073	6074
ば	ひ	ぶ	べ	ぼ
BA	HI	BU	BE	BO
6075	6076	6077	6078	6079
ぱ	ひ	ぶ	ペ	ぼ
PA	PI	FU	PE	PO

PART III

KATAKANA LIST

6100	6101	6102	6103	6104
アイウエオ	イ	ウ	エ	オ
A	I	U	E	O
6105	6106	6107	6108	6109
カキクケコ	キ	ク	ケ	コ
KA	KI	KU	KE	KO
6110	6111	6112	6113	6114
サシスセソ	シ	ス	セ	ン
SA	SHI	SU	SE	SO
6115	6116	6117	6118	6119
タチツテト	チ	ツ	テ	ト
TA	CHI	TSU	TE	TO

6120	6121	6122	6123	6124
NA	NI	NU	NE	NO
ハ	ヒ	フ	ヘ	ホ
HA	HI	FU	HE	HO
6130	6131	6132	6133	6134
マ	ミ	ム	メ	モ
MA	MI	MU	ME	MO
6135	6136	6137	6138	6139
ヤ	イ	ユ	エ	ヨ
YA	YI	YU	YE	YO

	6140	6141	6142	6143	6144
	RA	RI	RU	RE	RO
	6145	6146	6147	6148	6149
	WA	WI	WU	WE	WO
	6150				
	N				
	6155	6156	6157	6158	6159
	GA	GI	GU	GE	GO

ラ リ ル レ 口
ワ キ ウ ェ ヲ
ン
ガ ギ グ ゲ ゴ

6160	6161	6162	6163	6164
ザ	ジ	ズ	ゼ	ン
ZA	JI	ZU	ZE	ZO
6165	6166	6167	6168	6169
ダ	チ	ヅ	デ	ド
DA	JI	ZU	DE	DO
6170	6171	6172	6173	6174
バ	ビ	ブ	ベ	ボ
BA	BI	BU	BE	BO
6175	6176	6177	6178	6179
ぱ	ピ	ブ	ペ	ボ
PA	PI	PU	PE	PO

APPENDIX D

LEXICON OF JAPANESE

GENGOGAKU	言語学	LINGUISTICS
WA	は	NOMINATIVE PARTICLE
WO	を	ACCUSATIVE PARTICLE
GA	が	PREDICATIVE PARTICLE
TE	て	SUBORDINATE PARTICLE
KA	か	INTERROGATIVE PARTICLE
YO	よ	IMPERATIVE PARTICLE
NO	の	OF
NI	に	AT, IN
DE	で	BY
TO	と	WITH
E	へ	TO
KARA	から	FROM
YORI	より	THAN
MADE	まで	UNTIL
NI OITE	に於て	IN, AT
NI YOTTE	によつて	BY
TO TOMO NI	と共に	WITH
USHIRO	後	BACK
MAE	前	FRONT
SHITA	下	BOTTOM
UE	上	TOP
HIDARI	左	LEFT
MIGI	右	RIGHT
UCHI	内	INSIDE
SOTO	外	OUTSIDE
NAKA	中	MIDDLE
GAWA	側	SIDE
MAWARI	回り	VICINITY
AIDA	間	SPACE

TOKI	時	TIME
TAME	為	BEHALF
KAWARI	代り	EXCHANGE
KOCHIRA	こちら	HERE
SOCHIRA	そちら	THERE
ACHIRĀ	あちら	THERE
KOKO	此処	HERE
SOKO	其処	THERE
ASOKO	彼処	THERE
IMA	今	NOW
SONO TOKI	その時	THEN
DOKO	何処	WHERE
ITSU	何時	WHEN
NAZE	何故	WHY
IKAGA	如何	HOW
IKURA	幾ら	HOW MUCH
DONO KURAI	どの位	HOW FAR
NANBEN	何べん	HOW OFTEN
DO	どう	HOW
MOTTO	もつと	MORE
MOTTOMO	最も	MOST
DAKE	だけ	ONLY
DEMO	でも	EVEN
TAIHEN	大変	VERY
OKATA	大方	ALMOST
MO	もう	ALREADY
MADA	まだ	YET
MATA	又	AGAIN
AMARI	余り	TOO
KESSHITE	決して	NEVER

DOKOKA	何処か	SOMEWHERE
ITSUKA	何時か	SOMETIME
DŌKA JA	どうか	SOMEHOW
DOKODEMO	何処でも	ANYWHERE
ITSUDEMO	何時でも	ANYTIME
DŌDEMO	どうでも	ANYHOW
SHIJŪ	始終	ALWAYS
SHITAGATTE	従つて	THEREFORE
WATAKUSHI	私	I
ANATA	あなた	YOU
ANO KATA	あの方	HE, SHE
KARE	彼	HE
KANOJO	彼女	SHE
SORE	其	IT
WATAKUSHITACHI	私達	WE
ANATAGATA	あなた方	YOU
ANO KATATACHI	あの方達	THEY
KARERA	彼等	THEY
KORE	此	THIS
SORE	其	THAT
ARE	彼	THAT
KORERA	此等	THESE
SORERA	其等	THOSE
ARERA	彼等	THOSE
DONATA	どなた	WHO
DOCHIRA	どちら	WHICH
DARE	誰	WHO
DORE	どれ	WHICH
NANI	何	WHAT
HŌ	方	ONE

KAKUJI	各自	EACH
RYŌHŌ	両方	BOTH
SUBETE	総て	ALL
IKURAKA	幾らか	SOME, ANY
DONATAKA	どなたか	SOMEONE
DAREKA	誰か	SOMEBODY
NANIKA	何か	SOMETHING
DONATAMO	どなたも	NO ONE
DAREMO	誰も	NOBODY
NANIMO	何も	NOTHING
DONATADEMO	どなたでも	EVERYONE
DAREDEMO	誰でも	EVERYBODY
NANDEMO	何でも	EVERYTHING
WATAKUSHI NO	私の	MY
ANATA NO	あなたの	YOUR
ANO KATA NO	あの方の	HIS, HER
KARE NO	彼の	HIS
KANOJO NO	彼女の	HER
SONO	其の	ITS
WATAKUSHITACHI NO	私達の	OUR
ANATAGATA NO	あなた方の	YOUR
ANO KATATACHI NO	あの方達の	THEIR
KARERA NO	彼等の	THEIR
KONO	此の	THIS
SONO	其の	THAT
ANO	あの	THAT
KORERANO	此等の	THESE
SORERANO	其等の	THOSE
ARERANO	彼等の	THOSE
DONATA NO	どなたの	WHOSE

DOCHIRA NO	どちらの	WHICH
DARE NO	誰の	WHOSE
DONO	どの	WHICH
NANNO	何の	WHAT
HOKA NO	他の	OTHER
CHIISAI	小さい	SMALL
ŌKII	大きい	LARGE
HIKUI	低い	LOW
TAKAI	高い	HIGH
MIJIKAI	短い	SHORT
NAGAI	長い	LONG
HOSOI	細い	THIN
FUTOI	太い	THICK
CHIKAI	近い	NEAR
TOI	遠い	FAR
FURUI	古い	OLD
ATARASHII	新しい	NEW
OSOI	遅い	SLOW
HAYAI	速い	FAST
KARUI	軽い	LIGHT
OMOI	重い	HEAVY
ATSUI	熱い	HOT
TSUMETAI	冷たい	COLD
KURAI	暗い	DARK
AKARUI	明るい	BRIGHT
WARUI	悪い	BAD
YOI	良い	GOOD
KATAI	難い	DIFFICULT
YASUI	易い	EASY
MINIKUI	醜い	UGLY

UTSUKUSHII	美しい	BEAUTIFUL
KARAI	辛い	BITTER
AMAI	甘い	SWEET
ATSUI	暑い	HOT
SAMUI	寒い	COLD
KUROI	黒い	BLACK
SHIROI	白い	WHITE
AKAI	赤い	RED
KIIROI	黄いろい	YELLOW
AOI	青い	BLUE, GREEN
ARU	或る	SOME
ONAJI	同じ	SAME
MUKAI	向かい	OPPOSITE
KARANO	空の	EMPTY
MITSUNA	密な	DENSE
TSUNENO	常の	ORDINARY
INA	異な	STRANGE
SEITEKI	静的	STATIC
DŌTEKI	動的	KINETIC
JUNNA	純な	PURE
TOKUSEINO	特性の	SPECIAL
IPPANNO	一般の	GENERAL
OMONA	主な	PRINCIPAL
A-	亞	SUB-
CHŌ-	超	SUPER-
FU-	不	NON-
KATA-	片	ONE-WAY
FUKU-	複	TWO-WAY
KAKU-	各	EACH
MAI-	毎	EVERY

TAN-	单	SINGLE
TA-	多	MULTIPLE
BUN-	分	PART
ZEN-	全	ALL
SAI-	再	RE-
DAI-	第	-TH
KA-	可	-ABLE
-KA	化	-ATION
-TEKI	的	-ICAL
-SEI	性	-CITY
-DAI	大	-SIZE
-RUI	類	-LIKE
MU	無	NOTHING
HAN	半	HALF
KŌ	甲	FORMER
OTSU	乙	LATTER
TSUI	対	PAIR
SUKOSHI	少	FEW
TAKUSAN	沢	MANY
KAZU	山	NUMBER
ICHI	数	ONE
NI	一	TWO
SAN	二	THREE
SHI	三	FOUR
GO	四	FIVE
ROKU	五	SIX
SHICHI	六	SEVEN
HACHI	七	EIGHT
KU	八	NINE
JŪ	九	
	十	TEN

HYAKU	百	HUNDRED
SEN	千	THOUSAND
MAN	万	TEN THOUSAND
OKU	億	HUNDRED MILLION
HITOTSU	一つ	ONE
FUTATSU	二つ	TWO
MITSU	三つ	THREE
YOTSU	四つ	FOUR
ITSUTSU	五つ	FIVE
MUTSU	六つ	SIX
NANATSU	七つ	SEVEN
YATSU	八つ	EIGHT
KOKONOTSU	九つ	NINE
TŌ	十	TEN
TANI	单位	UNIT
MĒTORU	米	METER
GURAMU	瓦	GRAM
BYŌ	秒	SECOND
FUN	分	MINUTE
JI	時	HOUR
HI	日	DAY
TSUKI	月	MONTH
TOSHI	年	YEAR
DAI	代	AGE
ASA	朝	MORNING
GOZEN	午前	FORENOON
SHŌGO	正午	NOON
GOGO	午後	AFTERNOON
YŪGATA	夕方	EVENING
HIRU	昼	DAY

YORU	夜	NIGHT
KINŌ	昨日	YESTERDAY
KYŌ	今日	TODAY
ASHITA	明日	TOMORROW
HARU	春	SPRING
NATSU	夏	SUMMER
AKI	秋	AUTUMN
FUYU	冬	WINTER
MUKASHI	昔	ANTIQUITY
KAKO	過去	PAST
GENZAI	現在	PRESENT
MIRAI	未來	FUTURE
EIEN	永遠	ETERNITY
KAMI	紙	PAPER
HON	本	BOOK
SUMI	墨	INK
FUDE	筆	BRUSH
KAKU	画	STROKE
JI	字	CHARACTER
GŌ	号	SYMBOL
SŪ	数	NUMERAL
NA	名	NAME
GO	語	WORD
HYŌ	表	TABLE
ZU	図	DIAGRAM
E	絵	PICTURE
BUN	文	LITERATURE
DAI	題	TITLE
TEKIYŌ	摘要	ABSTRACT
ROMBUN	論文	DISSERTATION

SHINBUN	新聞	NEWSPAPER
JITEN	辞典	DICTIONARY
RAICHAKU	来着	ARRIVAL
SHUPPATSU	出発	DEPARTURE
YŌJI	用事	BUSINESS
SHISHUTSU	支出	EXPENDITURE
KŌTSŪ	交通	TRAFFIC
RI	利	ADVANTAGE
TETSUGAKU	哲学	PHILOSOPHY
IN	陰	YIN
YŌ	陽	YANG
KAI	界	REALM
RI	理	REASON
GENJITSU	現実	REAL
RISŌ	理想	IDEAL
KOTO	事	FACT
SHIN	真	TRUTH
HŌ	法	RULE
GENRI	原理	PRINCIPLE
KŌZON	恒存	CONSERVATION
FUHEN	不变	INVARIANCE
SŌTAISEI	相対性	RELATIVITY
SHINKA	進化	EVOLUTION
HI	非	WRONG
SEI	正	RIGHT
KI	機	OPPORTUNITY
JUTSU	術	STRATEGEM
GENIN	原因	CAUSE
KEKKA	結果	EFFECT
MONDAI	問題	PROBLEM

KENKYŪ	研究	RESEARCH
JIKKEN	実験	EXPERIMENT
RIRON	理論	THEORY
HŌHŌ	方法	METHOD
SOKUTEI	測定	MEASUREMENT
KEISAN	計算	COMPUTATION
HIKAKU	比較	COMPARISON
KAISHAKU	解釈	INTERPRETATION
REIKAN	靈感	INSPIRATION
KŌBUTSUKAI	鉱物界	MINERAL KINGDOM
SHOKUBUTSUKAI	植物界	VEGETABLE KINGDOM
DŌBUTSUKAI	動物界	ANIMAL KINGDOM
BIJUTSU	美術	ART
ONGAKU	音楽	MUSIC
KAGAKU	科学	SCIENCE
SHIZEN	自然	NATURE
ISHI	石	STONE
HISUI	翡翠	JADE
KANE	金	METAL
HAGANE	鋼	STEEL
KI	木	WOOD
TAKE	竹	BAMBOO
ASA	麻	HEMP
KAWA	革	LEATHER
KINU	絹	SILK
ZŌGE	象牙	IVORY
SUMI	炭	CHARCOAL
KŌ	香	INCENSE
SAKE	酒	RICE WINE
KUSURI	藥	MEDICINE

ABURA	油	OIL
NENRYŌ	燃料	FUEL
TSUCHI	土	GROUND
KŌRI	氷	ICE
MIZU	水	WATER
JŌKI	蒸氣	STEAM
KŪKI	空氣	AIR
HI	火	FIRE
TEN	天	SKY
TAI	體	BODY
MONO	物	OBJECT
MONO	者	PERSON
KOKORO	心	HEART
JIBUN	自分	SELF
KI	氣	SPIRIT
REI	靈	SOUL
AI	愛	LOVE
REI	例	EXAMPLE
KATA	型	MODEL
KEI	系	SYSTEM
MOTOI	基	BASIS
KYŪ	級	CLASS
HABA	幅	WIDTH
KATA	形	SHAPE
IRO	色	COLOR
MITSUDO	密度	DENSITY
CHIKARA	力	STRENGTH
KATA	方	MANNER
HODO	程	EXTENT
SHŌ	性	CHARACTER

DO	度	DEGREE
SHITSU	質	QUALITY
RYŌ	量	QUANTITY
TAISHŌ	対称	SYMMETRY
HANTAI SHŌ	反対称	ANTISYMMETRY
TŌHŌSEI	等方性	ISOTROPY
IHŌSEI	異方性	ANISOTROPY
JŌTAI	状態	STATE
DŌTŌ	同等	EQUIVALENCE
HEIKŌ	平衡	EQUILIBRIUM
SHINKŪ	真空	VACUUM
KITAI	気体	GAS
EKITAI	液体	LIQUID
KOTAI	固体	SOLID
RYŪTAI	流体	FLUID
KESSHŌ	結晶	CRYSTAL
SŌCHI	装置	APPARATUS
JIKKENSHITSU	実験室	LABORATORY
CHIRIGAKU	地理学	GEOGRAPHY
IDO	緯度	LATITUDE
KEIDO	経度	LONGITUDE
KITA	北	NORTH
MINAMI	南	SOUTH
HIGASHI	東	EAST
NISHI	西	WEST
HOKKYOKU	北極	NORTH POLE
HOKKYOKUKEN	北極圏	ARCTIC CIRCLE
KITA KAIKISEN	北回帰線	TROPIC OF CANCER
SEKIDŌ	赤道	EQUATOR
MINAMI KAIKISEN	南回帰線	TROPIC OF CAPRICORN

NANKYOKUKEN	南極圏	ANTARCTIC CIRCLE
NANKYOKU	南極	SOUTH POLE
NIHON	日本	JAPAN
AMERIKA	亞米利加	AMERICA
HOKUBEI	北米	NORTH AMERICA
NANBEI	南米	SOUTH AMERICA
YOROPPA	ヨーロッパ	EUROPE
AFURIKA	アフリカ	AFRICA
AJIA	アジア	ASIA
OSUTORARIA	オーストラリア	AUSTRALIA
CHUGOKU	中国	CHINA
MINAMOTO	源	SPRING
TAKI	滝	WATERFALL
KAWA	川	RIVER
UMI	海	SEA
SHIMA	島	ISLAND
RIKU	陸	LAND
TANI	谷	VALLEY
YAMA	山	MOUNTAIN
SAWA	沢	SWAMP
TA	田	RICE FIELD
MICHI	道	ROAD
HASHI	橋	BRIDGE
ZAI	在	COUNTRY
SATO	里	VILLAGE
SHI	市	CITY
KUNI	国	COUNTRY
JINKO	人口	POPULATION
MENSEKI	面積	AREA
KISHOGAKU	気象学	METEOROLOGY

TOONSEN	等温線	ISOTHERM
TOATSUSEN	等圧線	ISOBAR
RYUTSU	流通	CIRCULATION
TEIKIATSU	低気圧	CYCLONE
KOKIATSU	高気圧	ANTICYCLONE
ZENSEN	前線	FRONT
SORA	空	SKY
KUMO	雲	CLOUD
SOUN	層雲	STRATUS CLOUD
SEKIUN	積雲	CUMULUS CLOUD
KENUN	巻雲	CIRRUS CLOUD
KAZE	風	WIND
ARASHI	嵐	STORM
AME	雨	RAIN
YUKI	雪	SNOW
KAMINARI	雷	THUNDER
INABIKARI	稻光	LIGHTNING
ONDOKEI	温度計	THERMOMETER
KIATSUKEI	気圧計	BAROMETER
SHITSUDOKEI	湿度計	HYGROMETER
FUSOKUKEI	風速計	ANEMOMETER
KAGAKU	化学	CHEMISTRY
GENSO	元素	ELEMENT
KAGAKUKIGO	化学記号	CHEMICAL SYMBOL
GENSHIBANGO	原子番号	ATOMIC NUMBER
GENSHIRYO	原子量	ATOMIC WEIGHT
GENSHIKA	原子価	ATOMIC VALENCE
GENSHI	原子	ATOM
BUNSHI	分子	MOLECULE
KI	基	RADICAL

KACOBUTSU	化合物	COMPOUND
YOEKI	溶液	SOLUTION
SO	相	PHASE
KETSUGO	結合	BOND
KOZO	構造	STRUCTURE
SHIKI	式	FORMULA
HANNON	反応	REACTION
KANGEN	還元	REDUCTION
SANKA	酸化	OXIDATION
CHUWA	中和	NEUTRALIZATION
KASUIBUNKAI	加水分解	HYDROLYSIS
DENKAI	電解	ELECTROLYSIS
BUNSEKI	分析	ANALYSIS
SOGO	総合	SYNTHESIS
ENERUGI JUNI	エネルギー準位	ENERGY LEVEL
SUPIN RYOSHISU	スピノ量子数	SPIN QUANTUM NUMBER
KIDO RYOSHISU	軌道量子数	ORBITAL QUANTUM NUMBER
SHURYOSHISU	主量子数	PRINCIPAL QUANTUM NUMBER
SHUKIKEI	周期系	PERIODIC SYSTEM
SUISO	水素	HYDROGEN
HERIUMU	ヘリウム	HELIUM
RICHIMUMU	リチウム	LITHIUM
BERIRIUMU	ベリリウム	BERYLLOIUM
HOSO	硼素	BORON
TANSO	炭素	CARBON
CHISSO	窒素	NITROGEN
SANSO	酸素	OXYGEN
FUSSO	弗素	FLUORINE
NEON	ネオン	NEON
NATORIUMU	ナトリウム	SODIUM

MAGUNESHIUMU	マグネシウム	MAGNESIUM
ARUMINIUMU	アルミニウム	ALUMINUM
KEISO	珪素	SILICON
RIN	燐	PHOSPHORUS
ĪO	硫黄	SULPHUR
ENSO	塩素	CHLORINE
ARUGON	アルゴン	ARGON
KARIUMU	カリウム	POTASSIUM
KARUSHIUMU	カルシウム	CALCIUM
TETSU	鉄	IRON
DŌ	銅	COPPER
GIN	銀	SILVER
KIN	金	GOLD
MUKIKAGAKU	無機化学	INORGANIC CHEMISTRY
SAN	酸	ACID
ENKI	塩基	BASE
EN	塩	SALT
ION	イオン	ION
INION	陰イオン	ANION
YŌION	陽イオン	CATION
ANMONIUMU	アンモニウム	AMMONIUM
SUISANKABUTSU	水酸化物	HYDROXIDE
FUKKABUTSU	弗化物	FLUORIDE
ENKABUTSU	塩化物	CHLORIDE
TANSANEN	炭酸塩	CARBONATE
SHŌSANEN	硝酸塩	NITRATE
KEISANEN	珪酸塩	SILICATE
RINSANEN	燐酸塩	PHOSPHATE
RYŪSANEN	硫酸塩	SULPHATE
ENSOSANEN	塩素酸塩	CHLORATE

YŪKIKAGAKU	有機化学	ORGANIC CHEMISTRY
TANKASUISO	炭化水素	HYDROCARBON
ARUKŌRU	アルコール	ALCOHOL
ARUDEHIDO	アルデヒド	ALDEHYDE
SAN	酸	ACID
HAROGENKABUTSU	ハロゲン化物	HALIDE
SUISANKI	水酸基	HYDROXYL
AMINOKI	アミノ基	AMINO
MECHIRUKI	メチル基	METHYL
FENIRUKI	フェニル基	PHENYL
NITOROKI	ニトロ基	NITRO
KARUBONIRUKI	カルボニル基	CARBONYL
KARUBOKISHIRUKI	カルボキシル基	CARBOXYL
SHIANKABUTSU	シアノ化物	CYANIDE
BUTSURIGAKU	物理学	PHYSICS
KIKŌ	機構	MECHANISM
ON	音	SOUND
NETSU	熱	HEAT
HIKARI	光	LIGHT
DENKI	電気	ELECTRICITY
JIKI	磁気	MAGNETISM
SHITSURYŌ	質量	MASS
NAGASA	長さ	LENGTH
JIKAN	時間	TIME
TENBIN	天秤	BALANCE
SHAKUDO	尺度	SCALE
TOKEI	時計	CLOCK
ICHI	位置	POSITION
HENI	変位	DISPLACEMENT
SOKUDO	速度	VELOCITY

KASOKUDO	加速度	ACCELERATION
SHITSUTEN	質点	PARTICLE
CHIKARA	力	FORCE
UNDŌRYŌ	運動量	MOMENTUM
SAYŌ	作用	ACTION
HANSAYŌ	反作用	REACTION
SHŌDŌ	衝動	IMPULSE
SHIGOTO	仕事	WORK
SHIGOTORITSU	仕事率	POWER
ICHI ENERUGI	位置エネルギー	POTENTIAL ENERGY
UNDŌ ENERUGI	運動エネルギー	KINETIC ENERGY
KOTAI RIKIGAKU	固体力学	SOLID DYNAMICS
SHITSURYŌ CHŪSHIN	質量中心	CENTER OF MASS
KANSEI MŌMENTO	慣性モーメント	MOMENT OF INERTIA
SENUNDŌRYŌ	線運動量	LINEAR MOMENTUM
KAKUNDŌRYŌ	角運動量	ANGULAR MOMENTUM
CHIKARA	力	FORCE
TORUKU	トルク	TORQUE
HIZUMI	歪	STRAIN
ŌRYOKU	応力	STRESS
DANSEI	弹性	ELASTICITY
TATENAMI	縦波	LONGITUDINAL WAVE
YOKONAMI	横波	TRANSVERSE WAVE
RYŪTAI RIKIGAKU	流体力学	FLUID DYNAMICS
SHIO	潮	TIDE
NAMI	波	WAVE
HAKŌ	波高	WAVE HEIGHT
HARETSU	波列	WAVE TRAIN
NAGARE	流れ	CURRENT
WAKIDASHI	涌き出し	SOURCE

SUIKOMI	吸い込み	SINK
RYŪSOKU	流束	FLUX
RYŪSEN	流線	STREAM LINE
KASEN	渦線	VORTEX LINE
KYOKAISŌ	境界層	BOUNDARY LAYER
KŌRYŪ	後流	WAKE
SŌRYŪ	層流	LAMINAR FLOW
RANRYŪ	乱流	TURBULENT FLOW
AONSOKURYŪ	亜音速流	SUBSONIC FLOW
CHŌONSOKURYŪ	超音速流	SUPersonic FLOW
NENDO	粘度	VISCOSITY
NETSURIKIGAKU	熱力学	THERMODYNAMICS
ATSURYOKU	圧力	PRESSURE
ONDO	温度	TEMPERATURE
TAISEKI	体積	VOLUME
ZETTAI REIDO	絶対零度	ABSOLUTE ZERO
ENERUGI	エネルギー	ENERGY
ENTARUPI	エンタルピー	ENTHALPY
ENTOROPI	エントロピー	ENTROPY
HINETSU	比熱	SPECIFIC HEAT
DENKIRIKIGAKU	電気力学	ELECTRODYNAMICS
DENKA	電荷	ELECTRIC CHARGE
JIKYOKU	磁極	MAGNETIC POLE
DENRYŪ	電流	ELECTRIC CURRENT
JISOKU	磁束	MAGNETIC FLUX
CHOKURYŪ	直流	DIRECT CURRENT
KORYŪ	交流	ALTERNATING CURRENT
DENI	電位	ELECTRIC POTENTIAL
JII	磁位	MAGNETIC POTENTIAL
JŌKYŌ	場強	FIELD INTENSITY

DENJŌ	電場	ELECTRIC FIELD
JIJŌ	磁場	MAGNETIC FIELD
DENDŌRYOKU	電動力	ELECTROMOTIVE FORCE
JIDŌRYOKU	磁動力	MAGNETOMOTIVE FORCE
DŌDENSEI	導電性	CONDUCTIVITY
KAIRO	回路	CIRCUIT
CHOKURETSU	直列	SERIES
HEIRETSU	並列	PARALLEL
DENRYŪKEI	電流計	AMMETER
DENATSUKEI	電圧計	VOLTMETER
DENJIFUKUSHĀ	電磁輻射	ELECTROMAGNETIC RADIATION
KŌSOKU	光速	VELOCITY OF LIGHT
HANSHA	反射	REFLECTION
KUSSETSU	屈折	REFRACTION
KAISETSU	回折	DIFFRACTION
HENKŌ	偏光	POLARIZATION
KŌSEN	光線	LIGHT RAY
JŌKŌSEN	常光線	ORDINARY RAY
IJŌKŌSEN	異常光線	EXTRAORDINARY RAY
ZŌ	像	IMAGE
JITSUZŌ	実像	REAL IMAGE
KYOZŌ	虚像	VIRTUAL IMAGE
HAMEN	波面	WAVE FRONT
SHINPUKU	振幅	AMPLITUDE
ISŌ	位相	PHASE
SHŪHASŪ	周波数	FREQUENCY
HACHŌ	波長	WAVE LENGTH
SHŪKI	周期	PERIOD
HASŪ	波数	WAVE NUMBER
KŌDO	光度	INTENSITY

BUNKŌ	分光	SPECTRUM
KAKUBUTSURIGAKU	核物理学	NUCLEAR PHYSICS
RYŌSHI	量子	QUANTUM
KŌSHI	光子	PHOTON
CHŪSEIBISHI	中性微子	NEUTRINO
DENSHI	電子	ELECTRON
YŌDENSHI	陽電子	POSITRON
CHŪKANSHI	中間子	MESON
CHŪSEISHI	中性子	NEUTRON
YŌSHI	陽子	PROTON
JŪYŌSHI	重陽子	DEUTERON
SANJŪSHI	三重子	TRITON
KAKUSHU	核種	NUCLIDE
KAKU	核	NUCLEUS
RYŪSHI	粒子	PARTICLE
HANRYŪSHI	反粒子	ANTIPARTICLE
KAKUHANNŌ	核反応	NUCLEAR REACTION
GENSHIRO	原子炉	ATOMIC PILE
TEMMONGAKU	天文学	ASTRONOMY
SEKII	赤緯	DECLINATION
SEKIKEI	赤経	RIGHT ASCENSION
TOKYŪ	等級	MAGNITUDE
TAIYŌ	太陽	SUN
TSUKI	月	MOON
WAKUSEI	惑星	PLANET
SUISEI	水星	MERCURY
KINSEI	金星	VENUS
CHIKYŪ	地球	EARTH
KASEI	火星	MARS
MOKUSEI	木星	JUPITER

DOSEI	土星	SATURN
TENNOSEI	天王星	URANUS
KAIOSAI	海王星	NEPTUNE
HOSHI	星	STAR
SEIZA	星座	CONSTELLATION
GINGA	銀河	GALAXY
UCHU	宇宙	UNIVERSE
GESSHOKU	月食	LUNAR ECLIPSE
NISSHOKU	日食	SOLAR ECLIPSE
GENGETSU	弦月	CRESCENT MOON
KIDOU	軌道	ORBIT
KINCHITEN	近地点	PERIGEE
ENCHITEN	遠地点	APOGEE
KINJITSUTEN	近日点	PERIHELION
ENJITSUTEN	遠日点	APHELION
JURYOKUSAYO	重力作用	GRAVITATION
SUGAKU	数学	MATHEMATICS
SUCHI KAISEKIGAKU	数值解析学	NUMERICAL ANALYSIS
SEISU	正数	POSITIVE NUMBER
FUSU	负数	NEGATIVE NUMBER
ATAI	值	VALUE
ZETTAICHI	絶対值	ABSOLUTE VALUE
SOTAICHI	相対值	RELATIVE VALUE
RITSU	率	MODULUS
KEISU	係数	COEFFICIENT
HI	比	RATIO
KIGO KAISEKIGAKU	記号解析学	SYMBOLICAL ANALYSIS
KAGO	加号	ADDITION SIGN
GENGO	減号	SUBTRACTION SIGN
JOGO	乘号	MULTIPLICATION SIGN

JOGŌ	除号	DIVISION SIGN
TŌGŌ	等号	EQUALITY SIGN
KONGŌ	根号	RADICAL SIGN
WA	和	SUM
SA	差	DIFFERENCE
SEKI	積	PRODUCT
SHŌ	商	QUOTIENT
BUNSHI	分子	NUMERATOR
BUNBO	分母	DENOMINATOR
HŌTEISHIKI	方程式	EQUATION
FUTOSHIKI	不等式	INEQUALITY
SANJUTSU	算術	ARITHMETIC
SEISŪ	整数	INTEGER
BUNSŪ	分数	FRACTION
SOKO	底	BASE
SHISŪ	指数	INDEX
GYAKUSŪ	逆数	RECIPROCAL
TAISŪ	対数	LOGARITHM
SHINSŪ	真数	ANTILOGARITHM
SŌKEI	総計	TOTAL
HEIKIN	平均	MEAN
KAHŌ	加法	ADDITION
GENPŌ	減法	SUBTRACTION
JŌHŌ	乗法	MULTIPLICATION
JOHŌ	除法	DIVISION
KAIHŌ	解法	SOLUTION
KŌSHIKIKA	公式化	FORMULATION
KŌSŌ	構想	PLAN
BANGUMI	番組	PROGRAM
ANGŌ	暗号	CODE

KEISANKI	計算器	CALCULATOR
SANKAKUHŌ	三角法	TRIGONOMETRY
SEIGEN	正弦	SINE
YOGEN	余弦	COSINE
SEISETSU	正切	TANGENT
YOSETSU	余切	COTANGENT
SEIKATSU	正割	SECANT
YOKATSU	余割	COSECANT
GYAKUSEIGEN	逆正弦	ARCSINE
GYAKUSEISETSU	逆正切	ARCTANGENT
DAISŪGAKU	代数学	ALGEBRA
JŌ	乘	POWER
NIJŌ	二乘	SQUARE
SANJŌ	三乘	CUBE
KONSŪ	根数	ROOT
HEIHŌKON	平方根	SQUARE ROOT
RIPPOKON	立方根	CUBE ROOT
ISŪ	位数	ORDER
DAIICHII	第一位	FIRST
DAINII	第二位	SECOND
DAISANI	第三位	THIRD
JISŪ	次数	DEGREE
ICHIJI	一次	LINEAR
NIJI	二次	QUADRATIC
SANJI	三次	CUBIC
KŌ	項	TERM
IN	因	FACTOR
SHIKI	式	EXPRESSION
TAKŌSHIKI	多項式	POLYNOMIAL
KYŪSŪ	級数	SERIES

YŌSO	要素	ELEMENT
GYŌRETSU	行列	MATRIX
GYŌRETSUSHIKI	行列式	DETERMINANT
KOYŪ	固有	CHARACTERISTIC
HEISHIN	並進	TRANSLATION
KAITEN	回転	ROTATION
HANTEN	反転	INVERSION
DŌRAI	導來	DERIVATION
RISSHŌ	立証	PROOF
BIBUNGAKU	微分学	DIFFERENTIAL CALCULUS
DŌKANSŪ	導函数	DERIVATIVE
JŌDŌKANSŪ	常導函数	ORDINARY DERIVATIVE
HENDŌKANSŪ	偏導函数	PARTIAL DERIVATIVE
ZENDŌKANSŪ	全導函数	TOTAL DERIVATIVE
SEKIBUNGAKU	積分学	INTEGRAL CALCULUS
SEKIBUN	積分	INTEGRAL
FUTEISEKIBUN	不定積分	INDEFINITE INTEGRAL
DAENSEKIBUN	橢円積分	ELLIPTIC INTEGRAL
SENSEKIBUN	線積分	LINE INTEGRAL
MENSEKIBUN	面積分	SURFACE INTEGRAL
TAISEKIBUN	体積分	VOLUME INTEGRAL
KAISEKIGAKU	解析学	ANALYSIS
JISSŪ	実数	REAL NUMBER
KYOSŪ	虚数	IMAGINARY NUMBER
FUKUSOSŪ	複素数	COMPLEX NUMBER
KYŌYAKU	共役	CONJUGATE
HENKA	変化	VARIATION
RENZOKU	連続	CONTINUITY
TOKUI	特異	SINGULARITY
GENDO	限度	LIMIT

REI	零	ZERO
ENSHŪRITSU	円周率	PI
MUGENDAI	無限大	INFINITY
TEISŪ	定数	CONSTANT
HENSŪ	変数	VARIABLE
KANSŪ	函数	FUNCTION
GYAKUKANSŪ	逆函数	INVERSE FUNCTION
TŌSA KYŪSŪ	等差級数	ARITHMETIC SERIES
TŌHI KYŪSŪ	等比級数	GEOMETRIC SERIES
DAISŪKANSŪ	代数函数	ALGEBRAIC FUNCTION
SANKAKUKANSŪ	三角函数	TRIGONOMETRIC FUNCTION
SŌKYOKUKANSŪ	双曲函数	HYPERBOLIC FUNCTION
TAISŪKANSŪ	対数函数	LOGARITHMIC FUNCTION
SHISŪKANSŪ	指数函数	EXPONENTIAL FUNCTION
BESSERU KANSŪ	ベッセル函数	BESSEL FUNCTION
KIKAGAKU	几何学	GEOMETRY
TEN	点	POINT
SEN	線	LINE
HYŌMEN	表面	SURFACE
RITTAI	立体	SOLID
CHOKUSEN	直線	STRAIGHT LINE
CHIHEISEN	地平線	HORIZONTAL LINE
SHASEN	斜線	OBLIQUE LINE
SUICHOKUSEN	垂直線	VERTICAL LINE
CHOKURITSUSEN	直立線	VERTICAL LINE
HEIKŌSEN	平行線	PARALLEL LINES
SUISEN	垂線	PERPENDICULAR LINES
HEN	辺	SIDE
KADO	角	CORNER
SHAHEN	斜辺	HYPOTENUSE

SHAKAKU	斜角	OBLIQUE ANGLE
CHOKKAKU	直角	RIGHT ANGLE
HEIKAKU	平角	STRAIGHT ANGLE
SANKAKUKEI	三角形	TRIANGLE
SEIHŌKEI	正方形	SQUARE
HEIKŌSHIHENKEI	平行四辺形	PARALLELOGRAM
KYOKUSEN	曲線	CURVE
SESSEN	接線	TANGENT
HŌSEN	法線	NORMAL
KYOKURITSU	曲率	CURVATURE
KŌTEN	交点	INTERSECTION
EN	円	CIRCLE
CHŪSHIN	中心	CENTER
HANKEI	半径	RADIUS
CHOKKEI	直径	DIAMETER
GEN	弦	CHORD
KO	弧	ARC
ENSHŪ	円周	CIRCUMFERENCE
DAEN	橢円	ELLIPSE
HŌBUTSUSEN	放物線	PARABOLA
SŌKYOKUSEN	双曲線	HYPERBOLA
RETSU	列	ROW
SŌ	層	LAYER
HEIMEN	平面	PLANE
RIPPŌTAI	立方体	CUBE
CHŪ	柱	CYLINDER
KYŪ	球	SPHERE
GENTEN	原点	ORIGIN
ZAHYŌ	座標	COORDINATE
ŌZAHYŌ	横座標	ABSCISSA

JŪZAHYŌ	縱座標	ORDINATE
HEIKŌZAHYŌ	平行座標	CARTESIAN COORDINATES
HŌKŌ	方向	DIRECTION
KYORI	距離	DISTANCE
KYOKUZAHYŌ	極座標	POLAR COORDINATES
SEIBUN	成分	COMPONENT
JIGEN	次元	DIMENSION
KŪKĀN	空間	SPACE
SOKURYŌ	測量	METRIC
SOKUCHI	測地	GEODESIC
SUKARĀ	スカラ－	SCALAR
BEKUTORU	ベクトル	VECTOR
TENSORU	テンソル	TENSOR
POTENSHARU	ポテンシヤル	POTENTIAL
SŪRYŌSEKI	数量積	SCALAR PRODUCT
HŌKORYŌSEKI	方向量積	VECTOR PRODUCT
KEIDO	傾度	GRADIENT
HASSAN	発散	DIVERGENCE
KAITEN	回転	CURL
SEIBUTSUGAKU	生物学	BIOLOGY
SEI	生	LIFE
SHI	死	DEATH
SEI	性	SEX
OSU	雄	MALE
MESU	雌	FEMALE
SHU	種	SPECIES
KA	科	FAMILY
SAIBŌ	細胞	CELL
SHOKUBUTSUGAKU	植物学	BOTANY
NE	根	ROOT

MIKI	幹	TRUNK
EDA	枝	BRANCH
HA	葉	LEAF
HANA	花	FLOWER
TANE	種	SEED
KI	木	TREE
HAYASHI	林	GROVE
MORI	森	FOREST
MATSU	松	PINE
SAKURA	桜	CHERRY
YANAGI	柳	WILLOW
URI	瓜	MELON
INE	稻	RICE PLANT
KOME	米	RICE
MAME	豆	BEANS
MUGI	麦	WHEAT
CHA	茶	TEA
KUSA	草	GRASS
KIKU	菊	CHRYSANTHEMUM
DŌBUTSUGAKU	動物	ZOOLOGY
CHI	血	BLOOD
HONE	骨	BONE
NIKU	肉	FLESH
KAWA	皮	SKIN
KE	毛	HAIR
HANE	羽	FEATHER
HA	齒	TOOTH
KIBA	歯	TUSK
YUBI	牙	FINGER
SHITA	指	TONGUE
	舌	

TE	手	HAND
ASHI	足	FOOT
YOKU	翼	WING
O	尾	TAIL
KUBI	首	HEAD
ME	目	EYE
MIMI	耳	EAR
HANA	鼻	NOSE
KUCHI	口	MOUTH
MI	身	BODY
TAMAGO	卵	EGG
MUSHI	虫	INSECT
KAME	龜	TURTLE
KAI	貝	SHELLFISH
SAKANA	魚	FISH
TORI	鳥	BIRD
INU	犬	DOG
HITSUJI	羊	SHEEP
USHI	牛	COW
UMA	馬	HORSE
SHIKA	鹿	DEER
ZŌ	象	ELEPHANT
ONI	鬼	DEMON
TATSU	竜	DRAGON
JINRUIGAKU	人類学	ANTHROPOLOGY
HITO	人	MAN
OTOKO	男	MAN
ONNA	女	WOMAN
KO	子	CHILD
CHICHI	父	FATHER

HAHA	母	MOTHER
UJI	氏	FAMILY
SHIN	臣	RETAINER
KŌ	工	ARTISAN
SHI	士	WARRIOR
Ō	王	KING
BIJUTSUKA	美術家	ARTIST
KAGAKUSHYA	科學者	SCIENTIST
SEITO	生徒	STUDENT
SENSEI	先生	TEACHER
KUMI	組	CLASS
ITO	糸	THREAD
NUNO	布	CLOTH
KOROMO	衣	CLOTHES
ŌGI	扇	FAN
KAGO	籠	BASKET
TABA	束	BUNDLE
SHINA	品	ARTICLE
SARA	皿	DISH
UTSUWA	器	VESSEL
TAMA	玉	GEM
TO	灯	LAMP
TSUZUMI	鼓	DRUM
KATANA	刀	SWORD
HOKO	戈	HALBERD
MU	矛	SPEAR
YUMI	弓	BOW
YA	矢	ARROW
MATO	的	TARGET
ANA	穴	HOLE

BA	場	PLACE
NI	荷	LOAD
KUBIKI	衡	YOKE
KURUMA	車	VEHICLE
HO	帆	SAIL
HANSEN	帆船	SAILBOAT
TO	戸	DOOR
IE	家	HOUSE
TŌRŌ	灯籠	LANTERN
NIWA	庭	GARDEN
MON	門	GATE
HYŌ	標	MARKER
TŌ	塔	TOWER
TORII	鳥居	GATEWAY
KŌGAKU	工学	ENGINEERING
KŌGU	工具	TOOL
TEKO	挺子	LEVER
JIKU	軸	AXLE
YA	輻	SPOKE
RIN	輪	WHEEL
KUDA	管	PIPE
KIKAI	機械	MACHINE
KIKAN	機關	ENGINE
JIDŌSHA	自動車	AUTOMOBILE
RĒSSHA	列車	TRAIN
TETSUDŌ	鐵道	RAILWAY
KOBUNE	小舟	SMALL CRAFT
KISEN	汽船	STEAMSHIP
SUIJŌKI	水上機	HYDROPLANE
HIKŌKI	飛行機	AEROPLANE

TĀBIN	タービン	TURBINE
HATSUDENKI	発電機	GENERATOR
DENRYOKUSEN	電力線	POWER LINE
HENATSUKI	変圧器	TRANSFORMER
KAIHEIKI	開閉器	SWITCH
DENTŌ	電灯	ELECTRIC LIGHT
DENSHIKAN	電子管	ELECTRON TUBE
TORANJISUTĀ	トランジスター	TRANSISTOR
DENWA	電話	TELEPHONE
TEREBIJON	テレビジョン	TELEVISION
DENJISHAKU	電磁石	ELECTROMAGNET
DENDŌKI	電動機	MOTOR
ZŌFUKUKI	増幅器	AMPLIFIER
HASSHINKI	発振器	OSCILLATOR
IRU, ORU	居る	BE
ARU	有る	BE
DESU	です	BE
GOZARU	御座る	BE
HAJIMARU	始まる	START
TOMARU	止まる	STOP
TSUZUKU	続く	CONTINUE
OWARU	終る	END
KAWARU	変る	CHANGE
NARU	成る	BECOME
KURU	来る	COME
IKU, YUKU	行く	GO
KUDARU	下る	GO DOWN
AGARU	上がる	GO UP
HAIRU	入る	GO IN
DERU	出る	GO OUT

TŌRU	通る	GO THROUGH
MAWARU	回る	GO AROUND
SUGIRU	過ぎる	GO BY
TATSU	立つ	STAND UP
KAERU	帰る	RETURN
SARU	去る	LEAVE
ITARU	至る	REACH
HERU	減る	DECREASE
MASU	増す	INCREASE
AU	合う	AGREE
HANARERU	離れる	SEPARATE
CHIRU	散る	DISPERSE
SHIMARU	締まる	CLOSE
AKU	明く	OPEN
UGOKU	動く	MOVE
TENJIRU	転じる	TURN
TARERU	垂れる	HANG
KATAMUKU	傾く	TIILT
NOBIRU	伸びる	STRETCH
MAGARU	曲る	BEND
NEJIRERU	捩れる	TWIST
WARERU	割れる	CRACK
ORERU	折れる	BREAK
AMARU	余る	REMAIN
TSUMORU	積もる	ACCUMULATE
MUSU	蒸す	STEAM
YAKERU	焼ける	BURN
MOERU	燃える	BURN
HASHIRU	走る	RUN
TOBU	飛ぶ	FLY

FURU	降る	FALL
FURU	振る	SWING
FURUERU	震える	QUAKE
HAZUMU	弾む	SPRING
NAGARERU	流れる	FLOW
SUU	吸う	FLOW IN
WAKU	涌く	FLOW OUT
HIKARU	光る	SHINE
KUMORU	曇る	CLOUD UP
HARERU	晴れる	CLEAR UP
HENSURU	偏する	BE BIASED
KANSURU	関する	BE CONNECTED
UMARERU	生れる	BE BORN
HAERU	生える	GROW
YAMU	病む	BECOME ILL
NAORU	直る	BECOME WELL
OIRU	老いる	BECOME OLD
SHINU	死ぬ	DIE
SURU	為る	DO
MOCHIIRU	用いる	USE
MOTSU	持つ	HOLD
YŪSURU	有する	HAVE
HAJIMERU	始める	START
TOMERU	止める	STOP
TSUZUKERU	続ける	CONTINUE
OERU	終える	END
KAERU	変える	CHANGE
NASU	成す	ACHIEVE
HIKU	引く	PULL
OSU	押す	PUSH

KUDASARU	下さる	GIVE
AGERU	上げる	GIVE
IRERU	入れる	PUT IN
DASU	出す	PUT OUT
TOSU	通す	SEND THROUGH
MAWASU	回す	SEND AROUND
SUGOSU	過ぎす	SPEND
TATERU	立てる	SET UP
KISURU	帰する	ATTRIBUTE
SARU	去る	LEAVE
KAWARU	代る	REPLACE
HERASU	減らす	DECREASE
MASU	増す	INCREASE
AWASERU	合わせる	UNITE
HANASU	離す	SEPARATE
CHIRASU	散らす	DISPERSE
SHIMERU	締める	CLOSE
AKERU	明ける	OPEN
UGOKASU	動かす	MOVE
TENJIRU	転じる	TURN
TARASU	垂らす	HANG
KATAMUKERU	傾ける	TILT
NOBASU	伸ばす	STRETCH
MAGERU	曲げる	BEND
NEJIRU	捩る	TWIST
WARU	割る	CRACK
ORU	折る	BREAK
AMASU	余す	LEAVE
TSUMU	積む	ACCUMULATE
MUSU	蒸す	STEAM

YAKU	焼く	BURN
MOYASU	燃やす	BURN
TSUKURU	造る	MAKE
KAMAERU	構える	BUILD
KAKU	欠く	LACK
YOSURU	要する	NEED
TSUMU	摘む	PICK
SASAERU	支える	MAINTAIN
HOSU	干す	DRY
SHIMESU	湿す	MOISTEN
ASSURU	圧する	PRESS
MAKU	巻く	WIND
MUSUBU	結ぶ	BIND
TORU	取る	TAKE
OKU	置く	PLACE
HAKOBU	運ぶ	CARRY
HORU	放る	THROW
IRU	射る	SHOOT
ATARU	当る	HIT
KIRU	切る	CUT
KAWASU	交す	EXCHANGE
HANASU	放す	RELEASE
HANSURU	反する	OPPOSE
MICHIBIKU	導く	LEAD
SHITAGAU	従う	FOLLOW
HAKARU	計る	MEASURE
KURABERU	比べる	COMPARE
TABERU	食べる	EAT
MIRU	見る	SEE
KIKU	聞く	HEAR

KAGU	嗅ぐ	SMELL
AJIWAU	味わう	TASTE
SESSURU	接する	TOUCH
KANJIRU	感じる	FEEL
KIRU	着る	WEAR
KISERU	着せる	DRESS
RYŌRI SURU	料理する	COOK
IU, YUU	言う	SPEAK
KAKU	書く	WRITE
YOMU	読む	READ
TOU	問う	ASK
ŌJIRU	応じる	ANSWER
HANASU	話す	TALK
SHIMESU	示す	SHOW
RONJIRU	論じる	DISCUSS
OSHIERU	教える	TEACH
MANABU	学ぶ	LEARN
KANGAERU	考える	THINK
SHIRU	知る	KNOW
KESSURU	決する	DECIDE
KYŌSURU	供する	PRESENT
OMOU	思う	CONSIDER
KUWAERU	加える	ADD
GENJIRU	減じる	SUBTRACT
JŌJIRU	乗じる	MULTIPLY
JOSURU	除する	DIVIDE
KAGIRU	限る	LIMIT
TOKU	解く	SOLVE
TO	と	AND, OR
GA	が	BUT

OYABI	及び	AND
ARUIWA	或は	OR
SOSHITE	そして	AND
MATAWA	又は	OR
MOSHI	若し	IF
NAZENARABA	何故ならば	BECAUSE
MO	も	TOO, ALSO
GO	御	HONORIFIC PREFIX
HAI	はい	YES
IIE	いいえ	NO
KUDASAI	下さい	PLEASE
ARIGATO	有難う	THANK YOU
SO	そう	SO
OHAYO	お早う	GOOD MORNING
SAYONARA	さようなら	FAREWELL

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